Calcareous Nannofossil Biostratigraphy and Depositional History of the Late Cretaceous to Early Miocene Sequence of Iraq.

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A thesis submitted for the degree of Doctor of Philosophy
at the University of London
February 1994.

This work is dedicated to my wife Mirjana whose love and support has made this project possible.

ACKNOWLEDGEMENTS

Firstly I would like to thank my supervisors Prof. Alan Lord, Drs. Ted Finch and Bob Jones, whose help and guidance were invaluable during the production of this thesis.

I would also like to thank my sponsors The National Environmental Research Council and British Petroleum Limited whose financial support made this project possible.

My thanks also goes to the Iraq Petroleum Company in particular Mike Wilson and Ron Miller for allowing me access to and helping me gather stratigraphic information held in their archives. In addition I would like to thank Dr. Andrew Parker of Reading University who allowed me access to the samples used in this study.

My special thanks go to all my friends and colleagues in the Postgraduate Unit of Micropalaeontology in particular Dr. Paul Bown, Dr. Jackie Burnett, Dr. Elspeth Urquhart, Dave Rutledge and Dawn Windley for their advice and encouragement. My extra special thanks go to my close friends Dr. Spencer Roberts, Dr. Ruth Siddall and Llynne McCarthy for their help in production of this thesis and the encouragement they gave me during the darker days of my project. I would also like to thank all my friends in Regional Geology especially Dr. Robert Hall who allowed me access to the computing facilities used extensively to illustrate this thesis.

This thesis was produced with the full support and professional advice of the Micropalaeontology Unit technical staff Jim Davy and Toby Stiles. Thank you both for all your help.

My deep gratitude goes to my wife Mirjana, I dedicate this thesis to her as without her love and constant support I would of been committed years ago!.

Finally I would like to offer **no** thanks what so ever to Saddam Hussein whose purchase of a "Super Gun" and invasion of Kuwait caused no end of problems during this project.

ABSTRACT

This thesis presents a new calcareous nannofossil based zonation scheme for Iraq based upon the examination of 515 drill cutting, conventional core and bit samples from both southern and northern Iraq. This zonation consists of 13 zones and 7 subzones covering the Late Cretaceous to Early Miocene. To date no detailed nannofossil zonation scheme was available for Iraq and therefore the nannofossil zonation presented here breaks new ground. The new zonation scheme has also been successfully correlated with the established global calcareous nannofossil zonation schemes of Martini (1971), Okada and Bukry (1980) and Varol (1989). In addition, this zonation has been correlated with nannofossil zonation schemes applied in other Middle Eastern countries. These correlations have enabled Iraq to be put into a global and regional stratigraphic framework. The new zonation scheme has also been integrated with global planktonic foraminiferal zonation schemes and both planktonic and benthonic foraminiferal zonation schemes previously produced for Iraq. This was done to assess the dates previously assigned to the formations being analysed during this study. The new nannofossil scheme has also been correlated with the magnetobiostratigraphic timescale so that the timing of tectonic events, the duration of hiatuses and sedimentation rates could be assessed for the study area. This information has been used to refine the existing sediment deposition models believed to be active in Iraq during the time period studied. Finally, concentrations of certain nannofossil groups noted in the study area during particular time periods are explained with reference to regional and global environmental conditions associated with local salinity changes and global warming and cooling.

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CHAPTER ONE
INTRODUCTION

1.1 Previous Work:

Much of the geological work upon the Tertiary succession in Iraq, follows the oil exploration history which is outlined below. The stratigraphy of the area was established before 1961 by geologists from the Iraq Petroleum Company (I.P.C.) and its affiliated companies. After this date much of the geological studies were carried out by Iraqi geologists sometimes in conjunction with East European scientists. The majority of the micropalaeontological work on the Tertiary succession of Iraq concerns foraminifera (planktonic and benthonic). This work was mainly done by micropalaeontologists from I.P.C. and its affiliated companies including: P. Viennot, E.J. White, D.A. Grieg, F.R.S Henson, T.F. Grimsdale, F.E. Eames, A.H. Smout, H.V. Dunnington and R.C. van Bellen. In addition some palynological, algal and ostracod work has also been carried out on selected formations. However, only one Tertiary formation in Iraq has previously been studied for its calcareous nannofossil content; namely the Jaddala Formation from the Jebel Sinjar area, from which 90 samples were studied by El-Dawoody & Elewi (1984) to produce a zonation scheme. In the present study all of the 25 formations from the middle Palaeocene to lower Miocene succession have been studied and a new calcareous nannofossil zonation scheme was established based on 515 drill cutting, conventional core and bit samples.

1.2 History of Oil Exploration:

The first commercial oil discovery in Iraq was in 1927, in the Kirkuk Field. The Kirkuk Field was owned by the Iraq Petroleum Company (I.P.C.), a consortium comprising a number of international oil companies including British Petroleum Limited, which was then known as the Anglo-Iranian Oil Company. Following this discovery another consortium called the British Oilfield Development Company (B.O.D.) was established which gained concessions to the west of the River Tigris in the late 1920's and early 1930's. During this period sulphurous oil deposits were discovered in a number of structures in the Mosul area. These fields were not developed before the concessions were passed onto the Mosul Petroleum Company

(M.P.C.), which was affiliated to I.P.C. . Under the management of the M.P.C., after World War II, exploration within Iraq was increased and the Basrah Petroleum Company (B.P.C.) was established and like M.P.C. was affiliated to I.P.C. . The B.P.C. gained concessions in the southern part of Iraq. During the post-war period, the Butmah Field and the Ain Zalah Oil Fields were discovered by M.P.C. the later of which contains better quality oil, with a lower sulphur content. In addition I.P.C. discovered the Bai Hassan and Jambur Oil Fields and B.P.C. discovered the Rumailia and Zubair Oil Fields during this time period.

In 1961 exploration rights for I.P.C. and its affiliates were revoked by the Iraqi Government. The I.P.C. and its affiliates were allowed to produce their on-stream oil fields until 1972 when production was nationalised. In 1973, the state owned Iraqi Company for Oil Operations (I.C.O.O.) was established, which gradually took over the running of all on-stream production in the country. Also in 1964 the Iraq National Oil Company (I.N.O.C.) was founded which took over the exploration concessions in Iraq, outside the producing areas at that time. Later on the I.N.O.C. took over all petroleum exploration and production in Iraq. In the late 1960's the I.N.O.C. operated a number of service contracts with foreign oil companies including the French Elf-ETAP, the Indian Oil and Natural Gas Commission (O.N.G.C.) and Petrobras which led to discoveries in the south of Iraq in the former B.P.C. area. All foreign oil companies have now relinquished their contracts in Iraq, although recently a consortium of French oil companies has sought to take over the running of the Nahr Umr Oil Field in southern Iraq.

Iraq contains some of the supergiant fields of the world. For example, the Kirkuk Oil Field discovered in 1927 by I.P.C. produced 6×10^9 barrels of oil. The total recoverable reserves of oil for the Zagros foreland as a whole has been estimated at 200×10^9 barrels of oil (Beydoun *et al.*, 1992).

1.3 Objectives of Study:

The objectives of this present study are essentially five-fold:

1. Establish a detailed biostratigraphy for the Palaeocene to lower Miocene succession of Iraq based on calcareous nannofossils.
2. Integrate the calcareous nannofossil biostratigraphy with other microfossil zonation schemes produced previously for the study area.
3. Use the calcareous nannofossil zonation scheme to put Iraq into a regional and global time framework. However, it should be noted that little information exists on Tertiary calcareous nannofossils from the Middle East as a whole, however what does exist has been used.
4. Refine existing sediment deposition models by quantifying sedimentation rates by correlating the calcareous nannofossil zonation scheme presented in this study to the absolute time scale. Also to assess the palaeoenvironments and depositional regimes operating in the area during the time period studied.
5. This present study also seeks to bridge the geographical gap between the Mediterranean Sea and the Indian Ocean and record the consequences on marine communications of the closure and disappearance of the Tethys Ocean.

1.4 Study Area:

Iraq is approximately 450,000 sq. kms. in area, and is surrounded by Turkey in the north, Iran in the east, Kuwait and Saudi Arabia in the south, and Jordan and Syria in the west. Most of the oil in Iraq is concentrated in the northeast of the country, and because this present study is based on well material the sampling also tends to be concentrated in the northeast (see Figure 1.1).

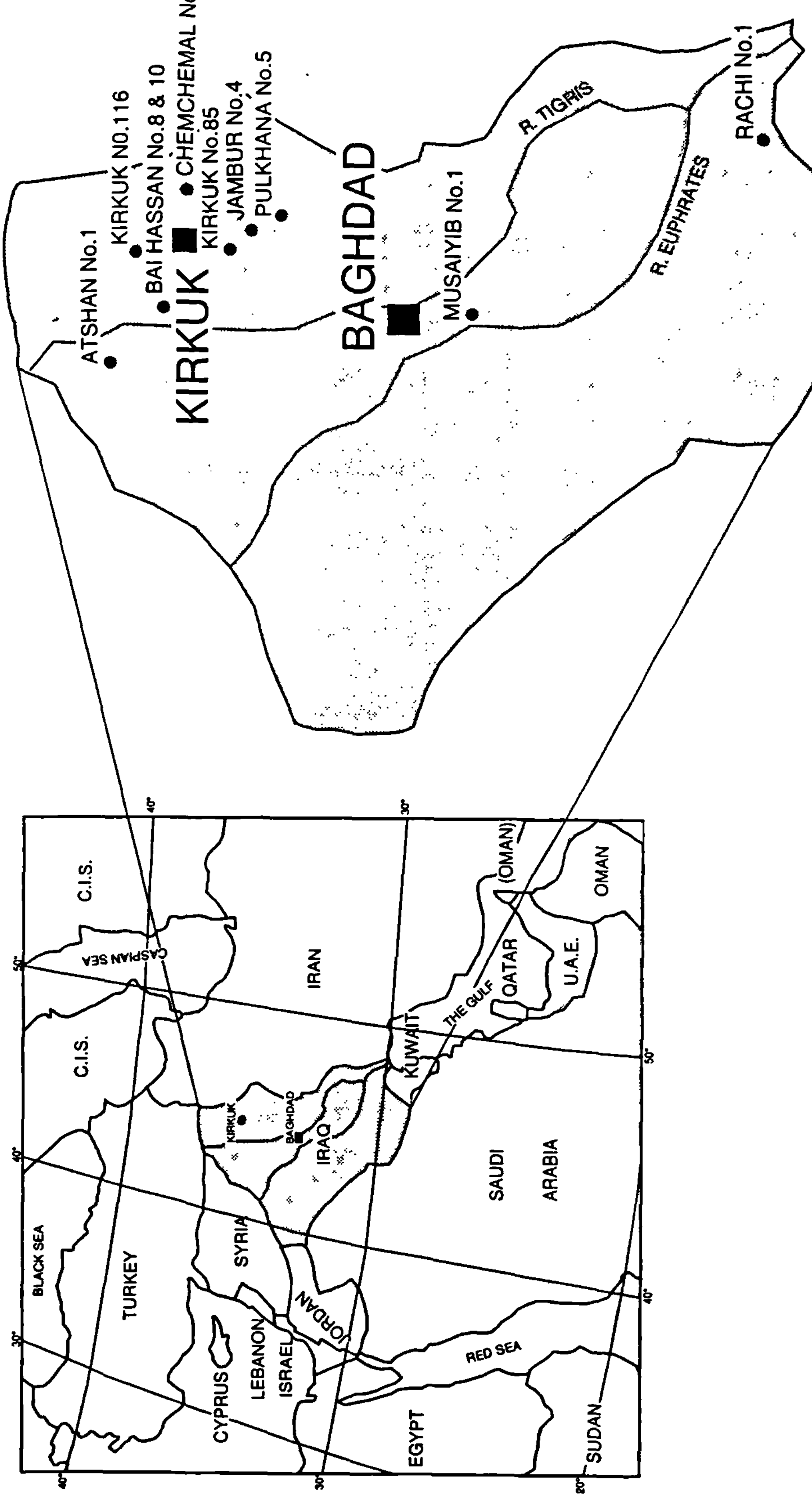


Figure 1.1. Location Map of Study Area.

CHAPTER TWO
GENERAL GEOLOGY

2.1 Introduction:

The stratigraphy of the studied area is shown in Figure 2.1 and is discussed in detail below, mainly following the major works on the study area by Dunnington (1958) and van Bellen *et al.* (1959). The stratigraphy has been discussed for both northern and southern Iraq and each area has been divided into four time-intervals; 1. Palaeocene to Early Eocene, 2. Mid to Late Eocene, 3. Oligocene (Early, Mid and Late) and 4. Early Miocene. Under each time-interval the stratigraphy, previous micropalaeontological work, the well sections studied, the lateral equivalents to the formations in other Middle Eastern countries, and the sedimentology and depositional history of the intervals is discussed. In addition, more information on the lithologies analysed from the well sections chosen for this study can be found in the well logs in Appendix A.

NORTHERN IRAQ

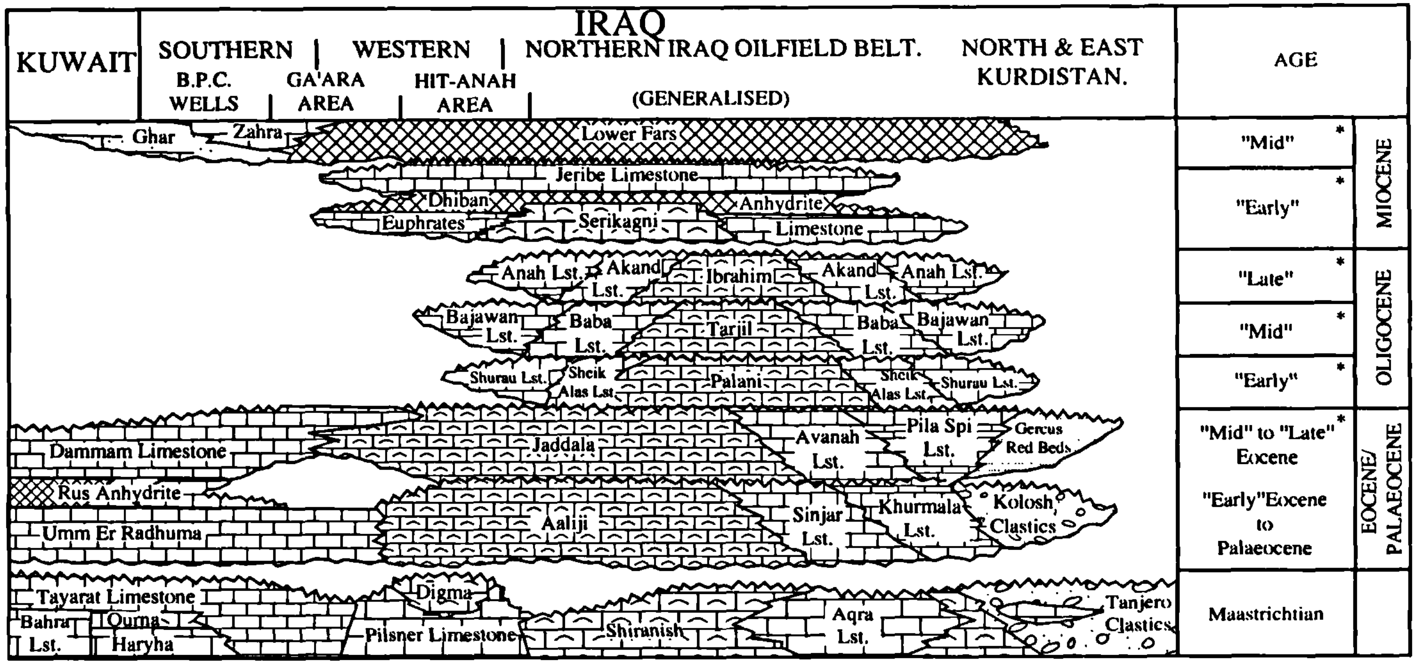
2.2 Palaeocene to Early Eocene.

Van Bellen *et al.* (1959) considered the Aaliji, Sinjar Limestone, Khurmala Limestone and Kolosh Clastics Formations to be within the Palaeocene to Early Eocene time-interval. However, they pointed out that there was no direct correlation to European standard Palaeocene and Early Eocene stages. A map showing the location of outcrop and well sections used in previous studies to describe the formations in this time-interval can be seen in Figure 2.2. In addition, a summary diagram of the biostratigraphic data from all these previous works can be seen in Figure 2.3.

2.2.1 Aaliji Formation:

Type Section: Outcrop section in northwestern Syria at Meidannki (Lat. 36° 29' 25''N, Long. 36° 53' 32''E).

Supplementary Type Section: I.P.C. Well Kirkuk No. 109 well section (Lat. 35° 33' 08''N, Long. 44° 08' 55''E), between the drilled depths of 758 metres (2487 feet) and



Key:

Anhydrites and Salt (with Limestones).
Backreef and Lagoonal Limestones.
"Basinal" Marls, Shales and Limestones.
"Flysch"-Like Calcareous Clastics.
Marine Sandstones, Siltstones and Variegated Clastics.
Neritic, Shoal and Shelf Limestones.
Red Beds.
Unconformity.
/ or ≶ Separate Units Which Intergrade or Interdigitate Laterally.
Base of a Transgressive Unit.
* Use of the Terms "Late", "Mid" and "Early" Does Not Infer Precise Correlation with any European Stages or Groups of Stages.

Figure 2.1 Chronostratigraphy Studied for the Late Cretaceous to "Mid" Miocene Period in Iraq (after Van Bellen *et al.*, 1959).

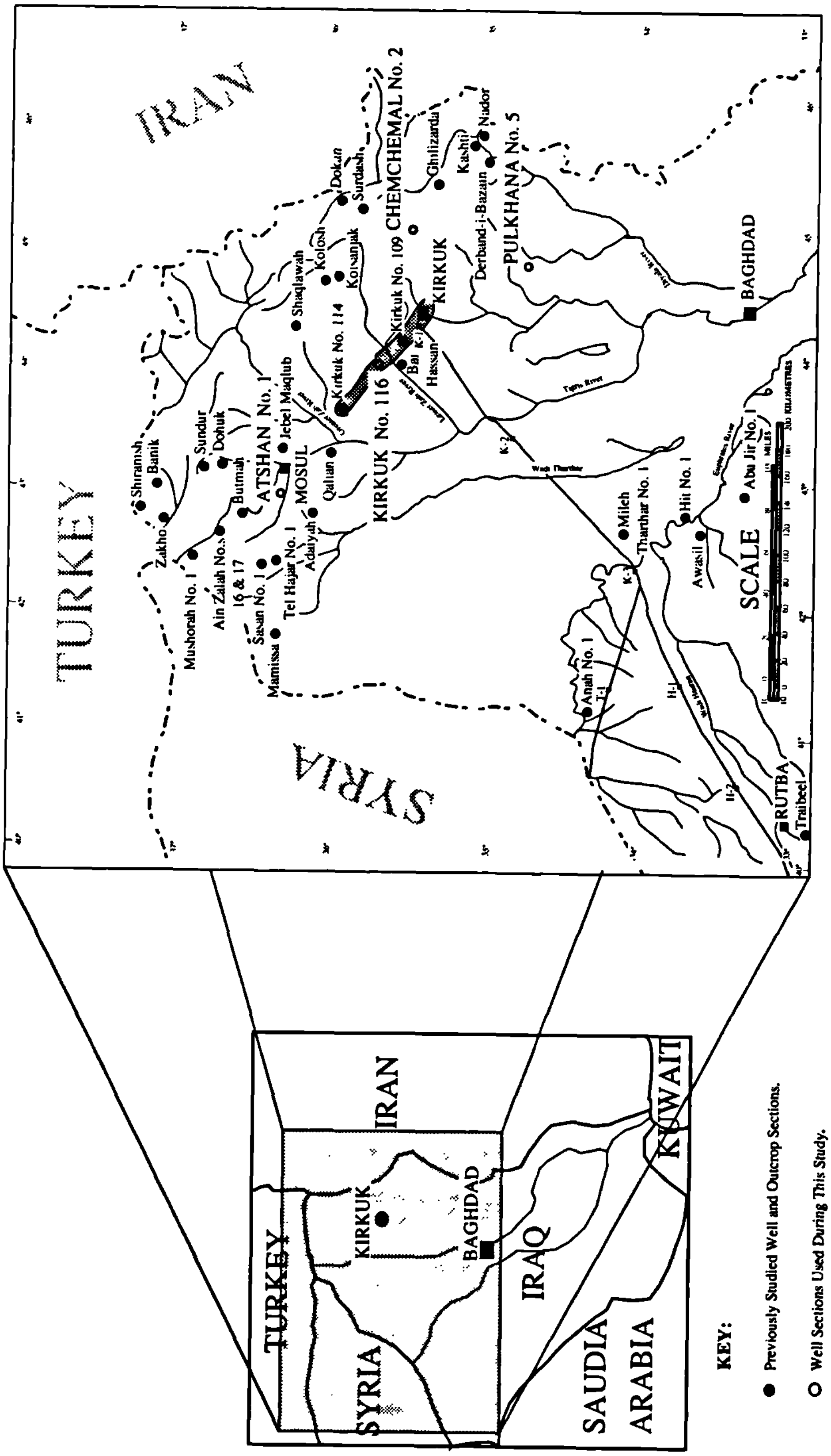


Figure 2.2 Location Map of Previously Studied Outcrop and Well Sections, and the Well Sections used during this Present Study for the Late Cretaceous to Early Eocene Time Interval.

925 metres (3035 feet).

Author(s): R.C. van Bellen (1950).

Synonyms: The "silty argillaceous, globigerinal marls" described by van Bellen (1956).

Lithological Characteristics/ Thickness: The lithology comprises generally grey and light brown silty argillaceous marls, marly limestones and shales with occasional macroscopic fragments of chert and rare generally scattered glauconite[1] grains. The Aaliji Formation is 167 metres (548 feet) thick at the type locality.

Al-Naquib (1960) described the Aaliji sediments from the Baba Dome area of the Kirkuk structure, and produced a more detailed account of the Aaliji Formation. He described them as comprising, in the upper part, dark grey globigerinal calcareous siltstones, which grade down into light grey and brown silty marls containing a thin globigerinal marly limestone towards the middle of the section.

Basal Contact: The Aaliji Formation rests on an erosive surface of the Late Cretaceous Shiranish Formation. The unconformity is marked by a distinctive lithology and faunal change (van Bellen, 1950 in van Bellen *et al.*, 1959).

However Al-Naquib (1960), points out a 3 metre (10 feet) thick layer of arenaceous, light grey, glauconitic[1] marl at the same boundary in the Baba Dome area.

Top Contact: The Aaliji Formation is unconformably overlain by the Jaddala Formation. The unconformity is marked by a distinctive change in lithology and fauna. Al-Naquib (1960), points out a marked colour change across the unconformity in the Baba Dome area.

Biostratigraphical Data: The Aaliji Formation has been dated as Palaeocene to "Early" Eocene in age in the supplementary type well section Kirkuk No. 109, based upon the planktonic foraminifera it contains. The Palaeocene has been dated from 862 metres (2827 feet) to 925 metres (3035 feet) and the Early Eocene has been recognised between the drilled depths of 758 metres (2487 feet) to 862 metres (2827 feet).

Al-Omari (1970) studied both the Shiranish and the Aaliji Formations from sub-surface sections of the following M.P.C. wells: Butmah No. 9, Ain Zalah Nos. 16 and

(1) Glauconite is a green mineral consisting of hydrated silicate iron, potassium aluminium and magnesium. The glauconite formed in a deep marine setting as a result of the oxidation of faecal pellets indicating a reduction in sedimentation rates.

17. He recorded planktonic foraminifera of Danian affinities from the lower part of the Aaliji Formation in Ain Zalah No. 17 and Butmah No. 9. However, an analysis of his Danian fauna indicates a younger age than Danian for this part of the Aaliji Formation.

Brun (1971) studied planktonic foraminifera from the Aaliji Formation in the subsurface sections of the Abu Grab and Buzirgan No.1 in southern Iraq. Analysis of these data suggests a Late Palaeocene age for the Aaliji Formation in these sections.

Kadouri (1978a) studied thin-sections of planktonic foraminifera from the Aaliji Formation within the well Tel Hajar No.1 in northwest Iraq. He assigned the Aaliji Formation in this well to the Danian based upon these observations. However, in other work Kadouri (1978b) reported a Late Palaeocene to Early Eocene age, again based upon planktonic foraminifera, from the same formation from the well S'Faiya No.3, also in northwest Iraq.

Al-Hashimi and Amer (1985) carried out a thin-section analysis of the planktonic foraminifera in the Palaeocene portion of the Aaliji Formation in the supplementary type well section in Iraq I.P.C. Well 109. They suggested a slightly older top to the formation than Kassab (1972, 1978 a,b), and also correlated the formation to the zonation system used by Blow (1979). They dated the top of the Aaliji Formation as Early Palaeocene (P1c ? P2) in age.

Kassab (1978a,b) studied the Cretaceous and Tertiary sequence in the same type well section, Kirkuk No. 109. He correlated his zones to Blow (1979) and also noted a large scale hiatus ranging from at least the Maastrichtian (*Abathomphalus mayaroensis* Zone) to the Mid Palaeocene (*Globorotalia pusilla pusilla* Zone, P3).

Kassab *et al.*(1986), produced a more detailed zonation for the Aaliji Formation from the M.P.C. Well Sasan No.1 in northwestern Iraq, based on 20 samples taken at roughly 3 metres (10 feet) intervals between the drilled depths of 230 metres (755 feet) and 309.4 metres (1015 feet). The zonation was based on the last occurrences of planktonic foraminifera, and in all six planktonic foraminiferal zones have been assigned to the Aaliji Formation:

Globorotalia formosa - Globorotalia aragonensis Zone (P7 to P8).

Globorotalia rex Zone (Upper part of P6).

Globorotalia velascoensis Zone (P5).

Globorotalia pusilla Zone (Upper part of P3).

Globorotalia angulata Zone (Lower part of P3).

Globorotalia uncinata Zone (P2).

Once Kassab *et al.* (1986) defined the six planktonic foraminiferal zones in the M.P.C. Well Sasan No.1 they correlated them with previous works on the Paleocene succession, by them and other authors, from outcrop sections in the Middle East and other parts of the world including the type Danian section in Denmark (Stevns Klint).

Distribution: The Aaliji Formation occurs west and southwest of a line running northwest - southeast just north of Kirkuk, between the Tigris River and the border of Iraq with Iran to the north of Chia Surkh. The Aaliji Formation is found in a number of M.P.C. wells; Anah No.1, Hit No.1, Abu Jir No.1, Fallujah No.1, Milehtharthar No.1, and in a number of wells in the Awasil area. In wells west of the Tigris between Qalian and Makhul, and in the Azkand section on the southern Dome of the Qarah Chauq Dagh, the Aaliji is absent or only very thinly developed.

Al-Naquib (1960), described sediments of the Aaliji formation from where they are thinly developed in the Injana area. Here, the Aaliji is a condensed sequence of grey streaky, foraminiferal limestones (with a common fauna of globigerinids and globorotalids) and greenish-grey bituminous marls. Similar sediments occur in the type area in Syria. The Aaliji Formation thickens towards the north and starts to interfinger with the Sinjar Limestone Formation, the Khurmala Formation and the Kolosh Formation.

2.2.2 Sinjar Limestone Formation:

Type Locality: Outcrop section in the village of Mamissa, on the Jebel Sinjar (Lat.

36° 22' 33''N, Long. 41° 41 23''E).

Author(s): Keller (1941).

Synonyms: "Calcaires brèchiques et calcaires massives" of Dubertret (1935).

Lithological Characteristics/ Thickness: The Sinjar Limestone Formation comprises a limestone with a calcareous algal reef component, a miliolid lagoonal component and a nummulitic shoal component. The limestone is usually recrystallised and yellow in colour and is 176 metres (577 feet) thick in the type area.

Al-Naquib (1960) also described the Sinjar Limestone Formation from the Avanah area of the Kirkuk structure where, the limestone is microdetrital, partly recrystallised, dolomitized and anhydritic, and contains *Solenomeris o'garmani* Douville, within the algal reef component.

Basal Contact: The Sinjar Limestone Formation rests unconformably on the Late Cretaceous Shiranish Formation. The unconformity is marked by a complete change in lithology and fauna.

Top Contact: The Sinjar Limestone Formation is overlain by the Jaddala Formation at the type outcrop section, but in the Kurdistan area the Sinjar Limestone Formation is overlain unconformably by the Gercüş Red Beds Formation. The upper contact at the type section is marked by a ravinement caused by wind erosion and a glauconite concentration.

Biostratigraphical Data: The Sinjar Limestone Formation has been assigned to the Palaeocene/ "Early" Eocene based on the benthonic foraminifera it contains.

Al-Naquib (1960) also recorded a Palaeocene/ "Early" Eocene benthonic foraminifera from the Sinjar Limestone Formation in the Avanah area of the Kirkuk structure.

Al-Sayyab and Al-Saddiki (1970), identified 18 algal and 5 benthonic foraminiferal species from the Palaeocene series of the Sinjar Limestone Formation from Jebal Sinjar in North Iraq.

Youkhana and Sissakian (1986), studied the Sinjar Limestone Formation in the Shaqlawa - Quwaisanjag area, and also identified benthonic foraminifera which they assigned to the Early Eocene.

Distribution: The Sinjar Limestone Formation occurs in numerous sections in mountainous areas, alone or interfingering with the Kolosh Clastics Formation. Well known localities include Kashti, Derband-i-Bazain, Koi Sanjak, Surdash, Sundur and Banik. The Sinjar Limestone Formation also occurs in a number of M.P.C. wells; Mushorah No.1, Alan No.1 and wells in the Butmah area. In these wells the Sinjar Limestone Formation interfingers with the Aaliji Formation and/ or the Kolosh Clastics Formation.

2.2.3 Kolosh Clastics Formation:

Type Locality: Outcrop section at Kolosh (Lat. 36° 09' 50'' N, Long. 44° 33' 45"E).

Author(s): Dunnington (1952).

Synonyms: Synonymous with part of the "Blue and purple shale group" of Richardson (1924) and the upper part of the "Shale series" of Noble (1926).

Lithological Chracteristics/ Thickness: The section is 686 metres (2250 feet) thick at the type locality and comprises shales, fine sandstones, marls and limestones. The shales and sandstones are composed of fragments of feldspar, quartz, rutile, garnet, and numerous other minerals.

Basal Contact: The Kolosh Clastics Formation unconformably rests upon the Tanjero Clastics Formation at the type section. The unconformity is marked by a total change of fauna without transitional elements.

Top Contact: The contact between the Gercüş Red Beds Formation and the underlying the Kolosh Clastics Formation at the type locality is probably unconformable. The uncertainty arises because in some areas the contact between the two formations appears gradational suggesting a conformable contact, but in the supplementary type section for the Gercüş Red Beds Formation, at Dohuk (Lat. 36° 52' 52'' N, Long. 43° 00' 36'' E), a conglomerate separates the two formations suggesting a break in sedimentation. This unconformity appears obvious because the Gercüş Red Beds Formation is predominantly red in colour and the Kolosh Clastics Formation is predominantly green in colour, but the Gercüş Formation does contain some green beds and the Kolosh Clastics Formation also contains some red beds.

Biostratigraphical Data: The succession at the type locality yielded benthonic and planktonic foraminifera and ostracoda, and is described in stratigraphic order below:

4. Blue shales and green marls with occasional smaller foraminifera including *Ammodiscus incertus* d'Orbigny, *Anomalinoides granosa* (Hantken), *Bulimina quadrata* Plummer, *Nodosaria zippei* Reuss, *Globigerina soldanii* d'Orbigny, *Loxostoma applinae* Plummer, *Nuttallides trumpyi* (Nuttall), and *Pseudovalvulinera* sp. : 506 metres (1660 feet).
3. Limestones with *Saudia labyrinthica* Henson, *Lockhartia* sp., miliolids, rotalids: 6 metres (19 feet).
2. Limestones with *Dictyokathina simplex* Smout, miliolids, rotalids, *Lockhartia* sp., and valvulinids: 30 metres (99 feet).
1. Limestones and marls with *Miscellanea miscella* (d'Archiac & Haime), ostracods, miliolids and valvulinids: 144 metres (472 feet).

The Kolosh Clastics Formation has been dated as Palaeocene to "Early" Eocene according to the fauna it contains. The "Early" Eocene age has been confirmed at Kashti approximately 145 kilometres (90 miles) ESE of Kirkuk, where *Aveolina oblonga* d'Orbigny occurs in limestones interdigitating with the Kolosh Clastics Formation.

Kassab (1978a) did not record any definite Early Palaeocene planktonic foraminifera from surface or subsurface sections in North and North East Iraq. The oldest Palaeocene planktonic foraminiferal assemblage recognized by Kassab was from the type Kolosh Formation (Kassab 1976, 1978b), and was assigned to Bolli's (1966), Mid Palaeocene *Globorotalia uncinata* Zone P2. The Early Palaeocene was also not encountered in Kolosh sections at Koisanjak and Shaqlawa towns in North East Iraq.

Kassab (1976) studied planktonic foraminifera ranges from the type outcrop section for the Kolosh Formation at Kolosh village. Eighty six samples were analysed and a detailed zonation scheme was established based upon ranges of species and abundances of individual species of planktonic foraminifera following Bolli (1966).

Kassab (1976) defined four zones in theses samples:

(a). *Globorotalia uncinata* Zone (P2).

(b). *Globorotalia angulata* Zone (Lower P3).

(c). *Globorotalia pusilla pusilla* Zone (Upper P3).

(d). *Lockhartia conditii* Zone.

The upper boundary of the *Globorotalia pusilla pusilla* Zone (Upper P3) is marked by a change in lithology from shales to limestones, and by the first appearance of benthonic foraminifera and the complete disappearance of planktonic foraminifera. This indicates a change in marine condition perhaps a lowering in sea-level in the area. The Tanjero Clastics Formation underlies the Kolosh Clastics Formation unconformably with a faunal break. The hiatus represents the Late Maastrichtian (Upper *Abathomphalus mayorensis* Subzone to *Globotruncana falsocalcarata* Subzone) to the Early Palaeocene and probably early Mid Palaeocene. Kassab (1976) also uses the planktonic foraminifera to correlate the Kolosh Clastics Formation with other parts of world.

Munim (1976) examined the planktonic foraminifera within two sections in the Dohuk area of North Iraq. Section 1 was found to range from Mid Maastrichtian to Late Palaeocene in age while Section 2 ranged from Mid Danian to Mid Palaeocene. Jacop (1978) did not recognise any positive Danian fauna in the same samples as Munim (1976) worked upon. Furthermore, Munim (1976) did not correlate the two sections even though they were only 500 metres apart. Al-Mutwali (1983) recognised an Early Palaeocene planktonic foraminiferal assemblage from the Kolosh Clastics Formation in the Shaqlawa area in North East Iraq (Kassab *et al.*, 1986).

Jassim et al. (1984) confirmed the presence of the Danian Stage in northwestern and western Iraq based upon the previous work of Cytyroky and Karim (1971), Al-Muttar (1976), Munim (1976), Amer (1977), Al-Omari (1970), Kadouri (1978a,b), and Al-Mutwali (1983) (Kassab *et al.*, 1986). They based their age determination on the planktonic foraminifera from a borehole sample from Traibeel in western Iraq, near the Jordanian border (Kassab *et al.*, 1986).

2.0 General Geology

Youkana and Sissakian (1986) studied the stratigraphy of the Shaqlawa to Quwaisanjag area, and dated the Kolosh Clastics Formation as earliest Mid Palaeocene to Early Eocene. This dating was based upon a mixed benthonic and planktonic foraminiferal assemblage.

Al-Shaibani, Al-Qayim and Salman (1986) studied the Cretaceous/ Tertiary boundary in the Dokan area in North Iraq. They collected only 6 samples, two from the Shiranish Formation (T1 and T2) and 4 samples from the base of the Kolosh Clastics Formation (K1-K4). They labelled the samples incorrectly, the Cretaceous samples should of been labelled K1 and K2, and the Tertiary samples should have been labelled T1-T4. They recorded planktonic foraminifera from the Kolosh Clastics Formation (Samples K1-K4) which they assigned to the Mid Thanetian P 3 Zone of Blow (1979).

Al-Shaibani and Al-Qayim (1986), studied the Cretaceous/ Tertiary contact between the Shiranish Formation (Late Cretaceous) and the Kolosh Clastics Formation in North West Iraq. They collected 14 samples across this boundary, of which 12 samples are in the Kolosh Clastics Formation. The base of the Kolosh Clastics Formation contained derived Cretaceous foraminifera: Globotruncaniids, *Heterohelix* sp., and a single benthonic foram *Bolivinoides draco draco*. Further up the section the Kolosh Clastics Formation contains planktonic foraminifera which they assigned to the Mid Thanetian P 3 zone of Blow 1979.

Al-Qayim and Al-Shaibani (1989), studied the Cretaceous/ Tertiary contact between the Shiranish Formation (Late Cretaceous) and the Kolosh Clastics Formation in an outcrop section in the village of Shiranish Islam 15 kms. northeast of Zakho, in northwest Iraq. They collected 20 samples from an 80 metre thick section and recorded a planktonic foraminifera which they assigned to the Mid Thanetian P 3 zone of Blow (1979) within the Kolosh Clastics Formation.

Distribution: The Kolosh Clastics Formation occurs in a broad, sinuous belt orientated approximately northwest - southeast, following the mountain front. The thickest development occurs along a zone running roughly through Koi Sanjak, continuing northwestward into Turkey under the Mushorah Dagh, where the Kolosh Clastics Formation occurs in M.P.C. Well Mushorah No.1, and then probably swings around into an East - West alignment. The Kolosh Clastics Formation is well exposed in Banik, Shiranish, Germawa, Sundur, Jebel Maqlub, Shaqlawah, Surdash, Derband-i-Bazian, Ghilizarda, Kashti, Nador, etc. . Subsurface sections include I.P.C. Well Chemchemal No.2 and wells on the Ain Zalah structure, where the clastics of the Kolosh Formation become subordinate to marine marls. The Kolosh Clastics Formation is heterogenous and the lithology varies horizontally and vertically, intergrading into and interfingering with the Sinjar Limestone Formation and the Khurmala Limestone Formation. In I.P.C. wells on the northern dome of the Kirkuk structure the Kolosh Clastics Formation has even been reported to occur in the Aaliji Formation occasionally. Southward and westward the Kolosh Clastics Formation passes into globigerinal marls and marly limestones.

2.2.4 Khurmala Limestone Formation:

Type Locality: Well section described from the I.P.C. Well Kirkuk No.114 (Lat. 45° 56' 15.50''N, Long. 43° 45' 21.78''E) between the drilled depths 983 metres (3225 feet) and 1176 metres (3860 feet).

Author(s): R.C. van Bellen (1953).

Synonyms: "Chemical Limestone" described by van Bellen (1956).

Lithological Characteristics/ Thickness: The lithology comprises a predominantly dolomitic limestone, in the type area, which is finely recrystallised and suboolitic in parts. The limestone is probably chemical and interfingers with, and grades down into the Kolosh Clastics Formation by interdigitation. The Kolosh Clastics comprises detrital chert, flint, radiolarite, and green silts and sands. Anhydrite also occurs but is probably secondary. The Khurmala Limestone Formation in type well section is approximately 185 metres (607 feet) true thickness. An exact thickness is difficult to assess because cross-bedding in the sandstones and conglomerates confuse dip estimates.

2.0 General Geology

Al-Naquib (1960) described the Khurmala Formation from a well on the Khurmala Dome of the Kirkuk structure. He also described the lithology as comprising grey, dolomitic, silty to marly, microgranular, recrystallised, tight limestones with rare marl and anhydrite nodules. These limestones occasionally alternate with fine to coarse grits and conglomerate bands of the Kolosh Clastics Formation. The conglomerate yields pebbles mainly of chert, radiolarite, anhydrite, dolomite and "green rock" with abundant interstitial pyrite. Towards the base of this succession small anhydritic nodules are common, and in the basal 4 metres (12 feet) there is a high percentage of quartz, chert and pyrite silt compared to the rest of the succession. The upper 142 metres (465 feet) is almost entirely porous dolomite, probably originally a chemical limestone, with fine quartz and occasional pyrite. Black pyritic shales also occur towards the top of this succession.

Basal Contact: The Khurmala Limestone Formation conformably rests upon the Kolosh Clastics Formation at the type section and grades down into the Kolosh Clatics Formation through interdigitation.

Top Contact: The Khurmala Limestone Formation (lagoonal facies) is unconformably overlain by the Avanah Limestone Formation, a shoal facies. The only way of producing the change from a lagoonal facies to a shoal facies is by a transgression. The existence of a transgression in the earliest "Mid" Eocene or in the latest "Early" Eocene is known throughout Iraq and elsewhere in the Middle East. If the transgression can be correlate over the area the underlying formation must be of "Early" Eocene and/ or Palaeocene age. This is confirmed in the type section as the Kolosh Clastics Formation of Palaeocene to "Early" Eocene age conformably underlies the Khurmala Limestone Formation. Further evidence that the transgression took place is noted in the I.P.C. Well Chemchemal No.2. Here the conglomeratic Gercüş Red Beds Formation unconformably overlies the Khurmala Limestone Formation.

Biostratigraphical Data: Fossil evidence is normally obliterated by recrystallisation and dolomitization however, miliolids, small valvulinids, clavulinids, very rare "ghosts" of indeterminate alveolinids, small gastropods and fragments of algae do occur, but unfortunately they are not determinable.

Al-Naquib (1960) also found rare fossils in the grit bands of the Kolosh Clastics Formation, within the Khurmala Limestone Formation, in a well on the Khurmala Dome of the Kirkuk structure. The fauna he identified includes; *Aveolina lepidula* Shwager, *Textularia* sp., miliolids, algae, valvulinids, and echinoid spines. Al-Naquib (1960) also recorded plant remains (leaves and spores) in the same well section and noted great lateral variations in lithology and faunal characteristics within the Khurmala Limestone Formation in a well approximately 230 kilometres (180 miles) along the Kirkuk structure from the Khurmala Dome, on the Avanah Dome in the southeast. Here the lithology comprises silty, anhydritic, porous limestones, with subordinate dense, grey limestone bands. The fauna is scattered and consists of textularids, valvulinids, miliolids, leached-out alveolinids, *Orbitolites* sp., and rare *Nummulites* sp.. Where the Khurmala Limestone Formation alternates with the Kolosh Formation the fauna includes: *Operculina* sp., *Discocyclina* sp., *Assilina* sp., *Nummulites* sp., and rare *Globorotalia* sp., *Bulimina* sp., *Gümbelina* sp., and globigerinids occur towards the base of this alternating sequence.
A Palaeocene to "Early" Eocene age was assigned to the Khurmala Limestone Formation. This is not based on fossil evidence but largely upon stratigraphic position.

Youkhana and Sissakian (1986) studied benthonic foraminifera from the Khurmala Limestone Formation in the Shaqlawa - Quawaisanjag area, in North Iraq. Using this evidence in conjunction with the stratigraphic position of the Khurmala Limestone Formation, they tentatively assigned the Khurmala Formation to the "Early" Eocene.

Distribution: The Khurmala Limestone Formation also outcrops in the core of the anticline at Jebel Maqlub, with intercalations of the Kolosh-type clastics similar to those found at the type well section. A number of I.P.C. wells on the northwest dome of the Kirkuk oilfield have also encountered the Khurmala Limestone Formation.

As part of their microfacies studies for the Tertiary of Iraq, Al-Hashimi and Amer (1985) recognised 7 planktonic foraminiferal zones and 3 benthonic foraminiferal zones for the Palaeocene to Early Eocene formations mentioned above based on subsurface and outcrop samples from a wide area of northern Iraq (see Figure 2.3).

2.2.5 Studied Well Sections:

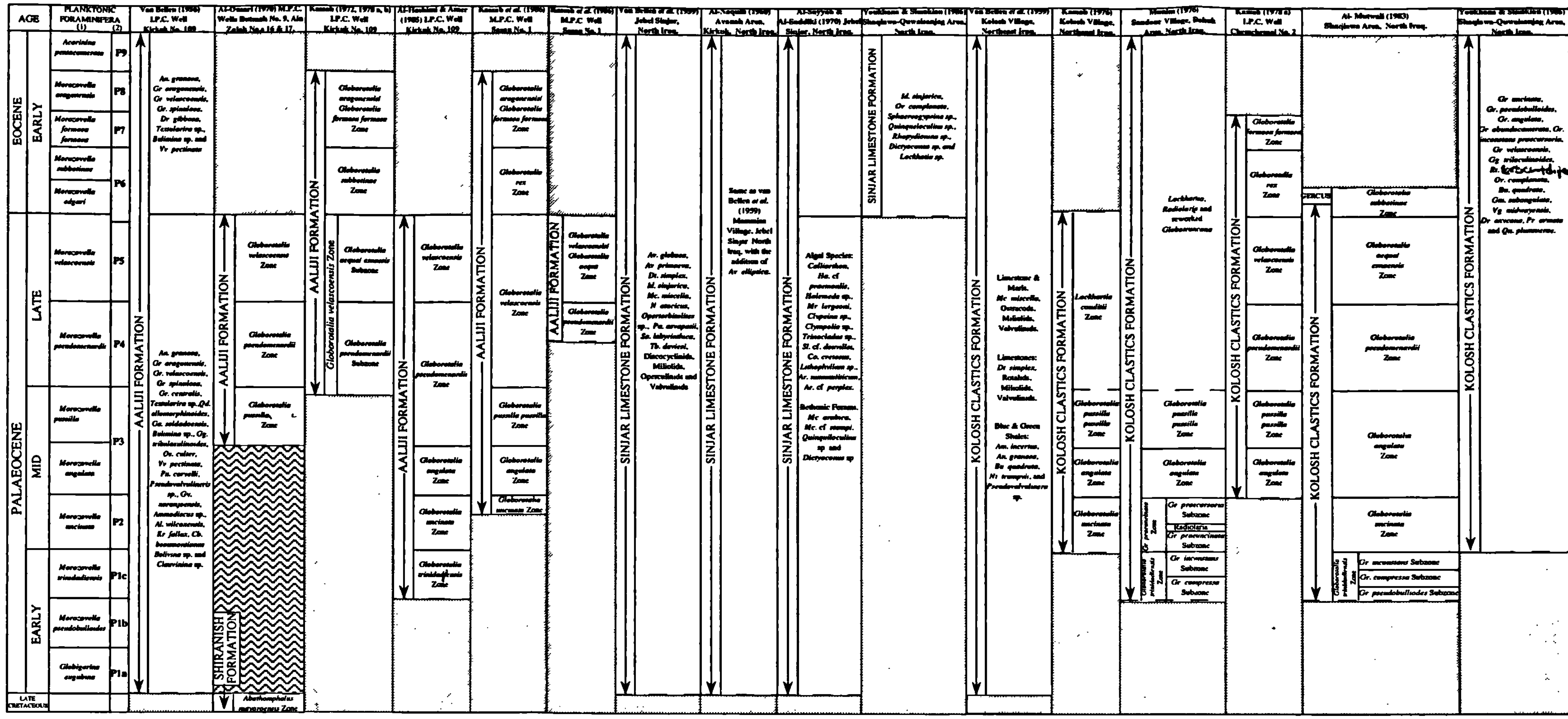
The Aaliji, Sinjar Limestone, Kolosh Clastics Formations are studied in Atshan No. 1, Chemchemal No. 2, Kirkuk No. 116 and Pulkhana No. 5 well sections in this study (see well logs for well sections in Appendix A).

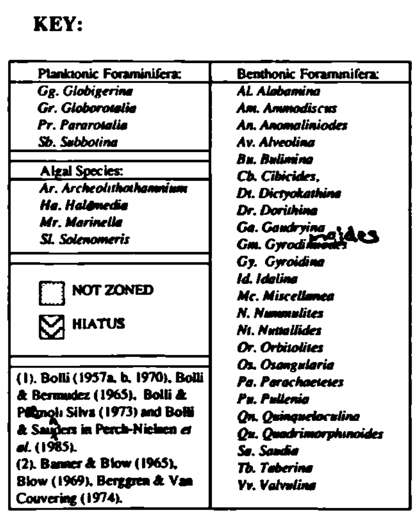
Atshan No. 1: The Aaliji and Khurmala Limestone Formations interfinger in this well section and two drill cutting samples were taken from the top of these formations (Sample No.s At-1/ 18 and At-1 19). The Khurmala Limestone/ Aaliji Formations are unconformably overlain by the Avanah Limestone/ Jaddala Formations, in this well section.

Chemchemal No. 2: The Aaliji and Kolosh Clastics Formations interfinger to produce a 707.4 metres (2358 feet) thick sequence in this well section. The Aaliji/ Kolosh Clastics Formations rest unconformably upon the Tanjero Clastics Formation, and are conformably overlain by the Sinjar Limestone Formation. The Sinjar Limestone Formation is 92.1 metres (307 feet) thick, and is overlain by the Khurmala Limestone Formation probably conformably. The Khurmala Limestone Formation is 76.5 metres (255 feet) thick, and is overlain by the Gercüş Red Beds Formation probably unconformably, as two beds of conglomerates make up this formation.

Kirkuk No. 116: The Aaliji Formation is 63 metres (210 feet) thick in this well section. The base of the Aaliji Formation lies unconformably upon the Shiranish Formation in this well section, and the top of the Aaliji Formation is overlain probably conformably, by the Kolosh Clastics Formation. Only the lower part of the Kolosh Clastics Formation was available for sampling in this well section.

Pulkhana No. 5: The Aaliji is 85.8 metres (286 feet) thick in this well section. The Aaliji Formation is unconformably underlain by the Shiranish Formation and





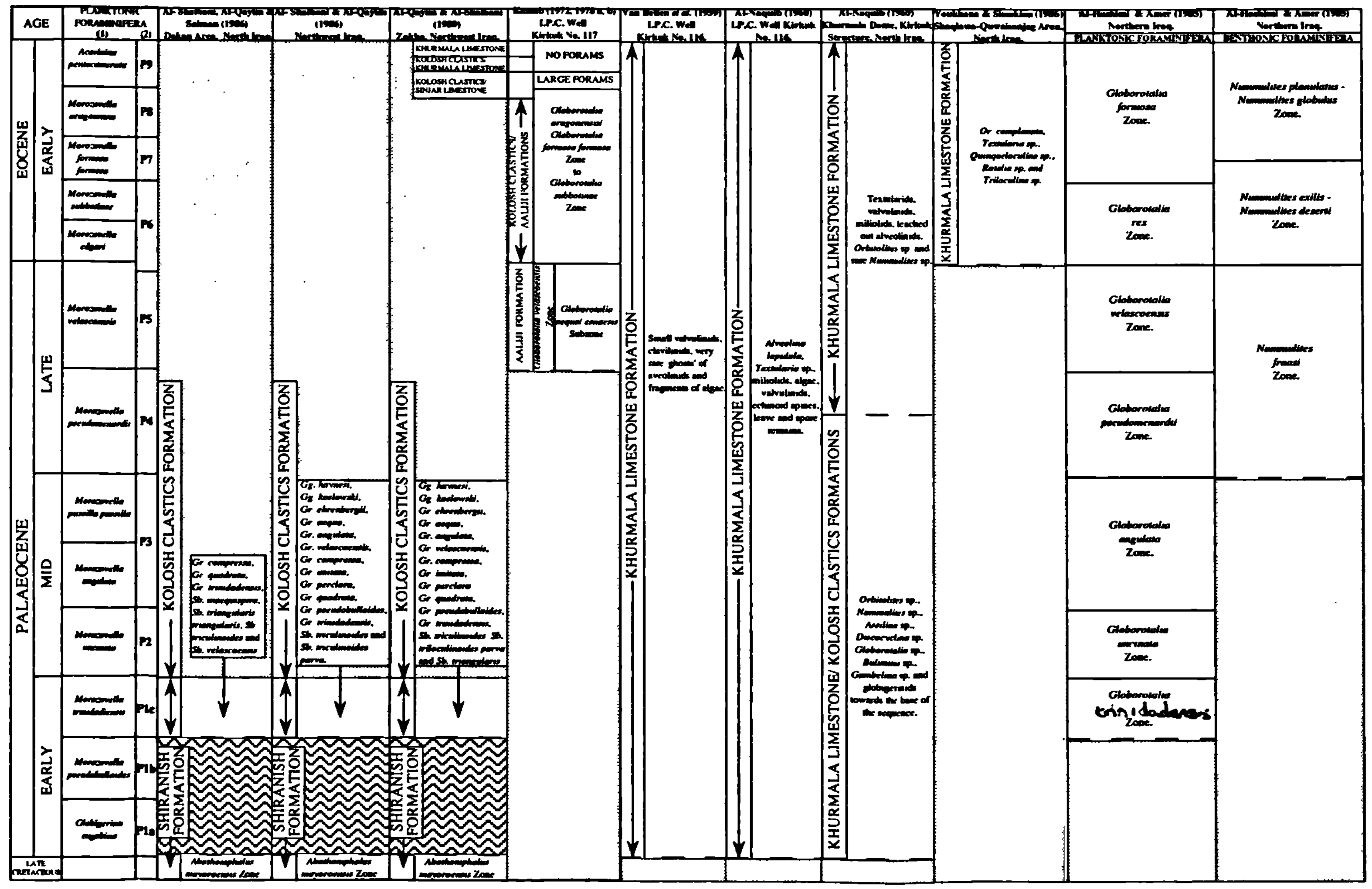


Figure 2.3 Previous Biostratigraphic Work for the Late Cretaceous to Early Eocene Succession of Northern Iraq.

unconformably overlain by the Jaddala Formation.

2.2.6 Regional Lateral Equivalents:

Following Beydoun (1988), the Aaliji, Sinjar Limestone, Khurmala Limestone and Kolosh Clastics Formations can be correlated with lateral equivalents in other Middle Eastern countries. In southeastern Turkey this group of formations can be correlated with parts of the Germav, Sinan, Kayakoy, Terbuzek, Gercüş, Beciraman and Ur Antak Formations. In southwestern Iran correlation can be made parts of the Pabdeh, Amiran, Kashkan, Taleh Zang, Sachun and Jahrum Formations. The Rus and Umm Er Radhuma Formations of southern Iraq, Kuwait, Saudi Arabia, Qatar and Abu Dhabi can be correlated with this group of formations along with the Rus and Umm Er Radhuma Formations, and the Pabdeh Formation from the mountains in the east of the United Arab Emirates (U.A.E.). This group of formations is equivalent to the Aaliji Formation in Syria, the Taqiye Formation in Jordan, and the lower part of the Shephela Group (Taqiya Formation) in Israel, and also has unnamed lateral equivalents in the Lebanon coastal region.

2.2.7 Sedimentology and Depositional History:

The sedimentology and depositional history for this time interval is based upon van Bellen *et al.* (1959), Dunnington (1958), Buday *et al.* (1980) and Al-Hashimi and Amer (1986) and Beydoun (1989), and is illustrated in Figure 2.4. The effects of the Laramide orogenic movements at the Late Cretaceous/ Palaeocene boundary in Iraq resulted in a period of folding, thrusting and orogenic uplift. This led to an interval of widespread erosion and regression which took place over a wide area of Iraq, so that the Palaeocene to Early Eocene succession rests unconformably upon the Late Cretaceous. The northeast remained as a topographic high, whilst downwarping occurred to the southwest in an area formerly occupied by a Late Cretaceous flysch trough. Sedimentation began anew in this area with the creation of a broad northwest-southeast linear flysch trough which ran from Shiranish in the northwest to Kashti in the southeast. This Tertiary flysch trough was filled with detrital limestones and shales of the Kolosh Clastics Formation, which were erosional products from a topographic high towards the northeast. Reef carbonates of the Sinjar Limestone

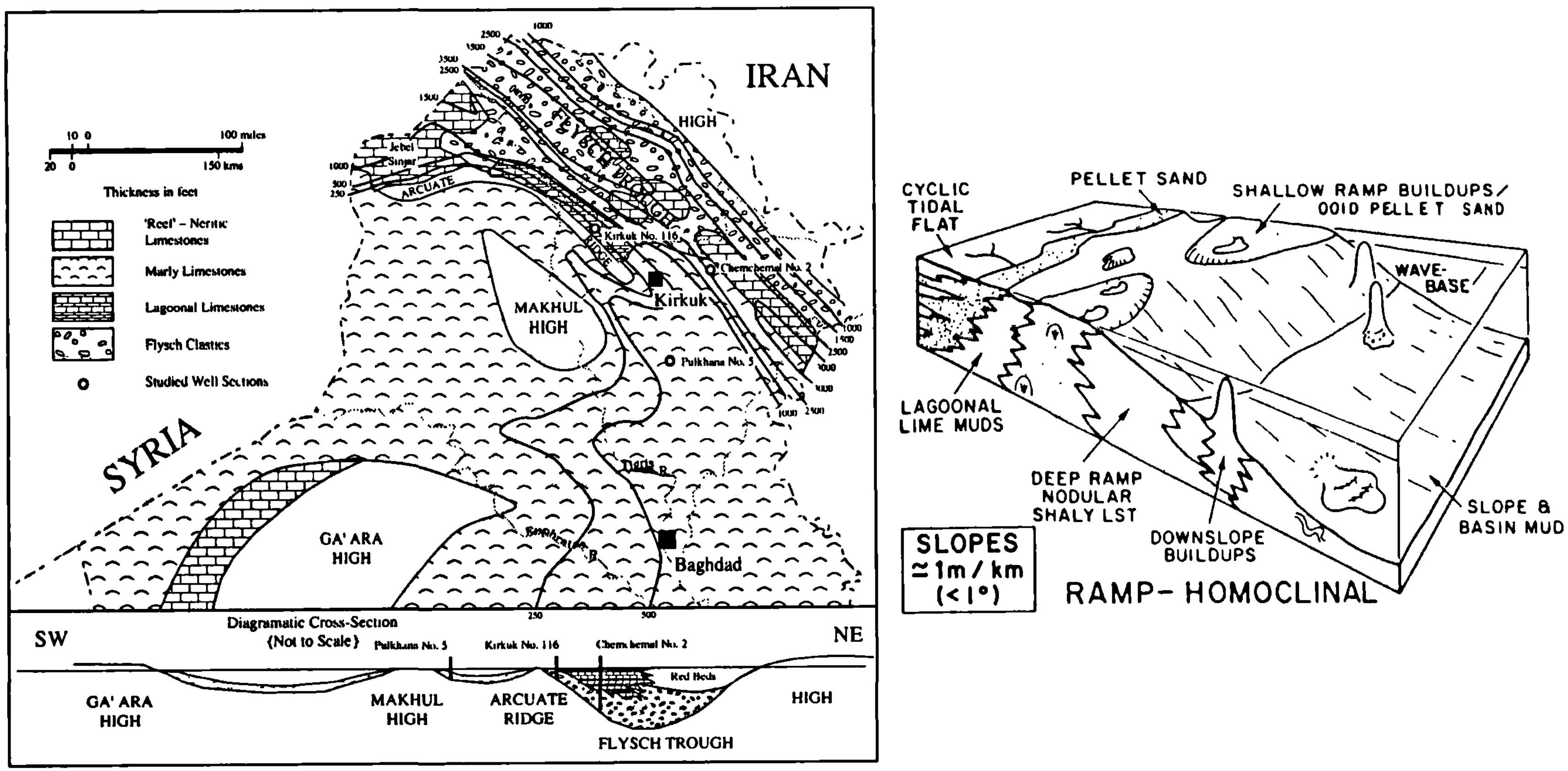


Figure 2.4. Isopach-Facies Map & Model for the Paleocene-Early Eocene of Northern Iraq (Partly modified after Dunnington, 1958 & Read, 1985 respectively).

Formation developed on some areas of the southwestern margin of this flysch trough. Behind this partial barrier, lagoonal limestones of the Khurmala Limestone Formation developed. In front of this emergent land towards the northeast open marine globigerinal marls of the Aaliji Formation developed. Dunnington (1958) suggested that towards the end of the deposition of the Kolosh Clastics into the flysch trough, red beds of the Gercüş Red Beds Formation were deposited, however this formation has been considered under the next time slice the Mid to Late Eocene.

Majid and Veizer (1986) suggest a similar model based upon the work of Read (1985), with the formation of a clastic ramp made up of sediments from the Kolosh Clastics and Aaliji Formations. This clastic ramp evolved later into a rimmed carbonate shelf on which restricted lagoonal carbonates of the Khurmala Limestone Formation developed behind Sinjar Limestone bioherms. They suggested the facies change from bioherm to basinal sediments was fault controlled, and was situated in the vicinity of the I.P.C. Well Kirkuk No. 116, one of the well sections sampled for this study. This sediment deposition model is illustrated in Figure 2.4 along with a map of the distribution of formations in the Palaeocene to Early Eocene time interval. Majid and Veizer (1986) preferred the term bioherm to reef to describe the Sinjar Limestones as the limestone lack frame-building organisms in their growth positions. They also studied the geochemical nature of the nearshore and offshore basinal sediments and found that the nearshore sediments had low sodium and strontium contents as well as light $\delta^{18}O$ and $\delta^{13}C$. In contrast the basinal sediments have the opposite attributes and foreshore deposits had intermediate sodium, strontium and oxygen and carbon contents. Majid and Veizer (1986) explained these results by the fact that nearshore sediments in the nearshore area were deposited in water with a marked meteoric aspect while the basinal sediments were laid down in water with a similar composition to present day seawater. The foreslope sediments were deposited in waters with intermediate compositions between meteoric water and seawater. This relatively simple model for this group of formations is complicated, as interfingering and intergrading occurs between these formations reflecting the effectiveness of the "reef"-type (bioherm) limestones as a barrier. Deposition in the northern area was also controlled by a complex set of topographic highs and lows. Four prominent topographic highs were present in northern Iraq during the Palaeocene to Early Eocene period:

(1). In the extreme northeast of Iraq and sediments derived from it were shed into the main broad, linear northwest-southeast trough towards the southwest.

(2). An arcuate ridge south of Jebel Sinjar through Adaiyah and Qalian to just south of Bai Hassan. The combined effect of this arcuate barrier and the rapid subsidence of the trough behind it, enabled large amounts of sediment to be trap and accommodated in the flysch trough. This led to sediment starved conditions to developed to the southwest of the arcuate barrier. The sediments then increase in thickness again beyond the Euphrates River towards the Ga'ara High as a result of erosional products being shed into the basin from the high.

(3). The Makul High which occurs to the southwest of the arcuate barrier and is smaller but broader than the previous barrier. It is not entirely clear whether this high was actually emergent it may of represented a shoal or bank in front on the arcuate barrier to the north.

(4). The Ga'ara High occurs in the southwestern corner of the northern area of Iraq, and has developed cherty phosphatic marls and neritic-littoral limestones on its northwestern flank. These sediments are similar in some respects to the Aaliji and Sinjar Limestone Formations of northern Iraq, but actually form the Akshat phosphatic deposits part of the Umm Er Radhuma Formation of southern Iraq. The phosphatic nature of the sediments indicates that they were also laid down in a oxygen depleted, reducing environment.

The sediments deposited during the Palaeocene to Early Eocene time were relatively undisturbed until early in the Eocene when folding began to occur in the internal parts of this basin. Further orogenic movements led to the uplift and wide spread erosion of the area. The area was then drowned by the late Early Eocene marine transgression which led to the Mid to Late Eocene deposits being unconformably deposited on the Palaeocene to Early Eocene sediments.

2.3 Mid to Late Eocene.

Van Bellen *et al.* (1959) placed the Jaddala, Avanah Limestone, Pila Spi Limestone and Gercüş Red Beds Formations into this time-interval. However, they pointed out that there is no direct correlation to the European standard Mid and Late Eocene. A map showing the location of outcrop and well sections used in previous studies to describe the formations in this time-interval can be seen in Figure 2.5. In addition, a summary diagram of the biostratigraphic data from all these previous works can be seen in Figure 2.6.

2.3.1 Jaddala Formation:

Type Section: Outcrop section at Jaddala village (Lat. 36° 18' 20'' N, Long. 41° 41' 28'' E).

Author(s): Henson (1950).

Synonyms: "Marnes claires jaunâtres" of Dubertret (1935), "Globigerina limestone" of Barber (1948), "Globigerinal marls and limestones" of Baker (1953), "GEM" of Daniel (1954), "GEU" of Daniel (1954) and "Globigerinal marl" of van Bellen (1956).

Lithological Characteristics/ Thickness: The type section comprises marly and chalky limestones and marls with occasional thin intercalations of shoal limestones (Avanah Limestone tongues). The Jaddala Formation is 343 metres (1124 feet) thick at the type section.

Basal Contact: The Jaddala Formation rests unconformable upon the Sinjar Limestone Formation at the type locality. The unconformity is marked by a glauconite concentration in the base of the Jaddala Formation

Top Contact: The Jaddala Formation is unconformably overlain by the "Early" Miocene Serikagni Formation at the type section.

Biostratigraphical Data: The Jaddala Formation at the type section contains a planktonic foraminiferal assemblage from the "Mid" to "Late" Eocene. Towards the base of the Jaddala Formation at the type section a planktonic foraminiferal assemblage occurs considered to be derived, but some authorities regard it as evidence of a "Early" Eocene age. Some horizons within the Jaddala Formation also contain *Radiolaria* and sponge spicules.

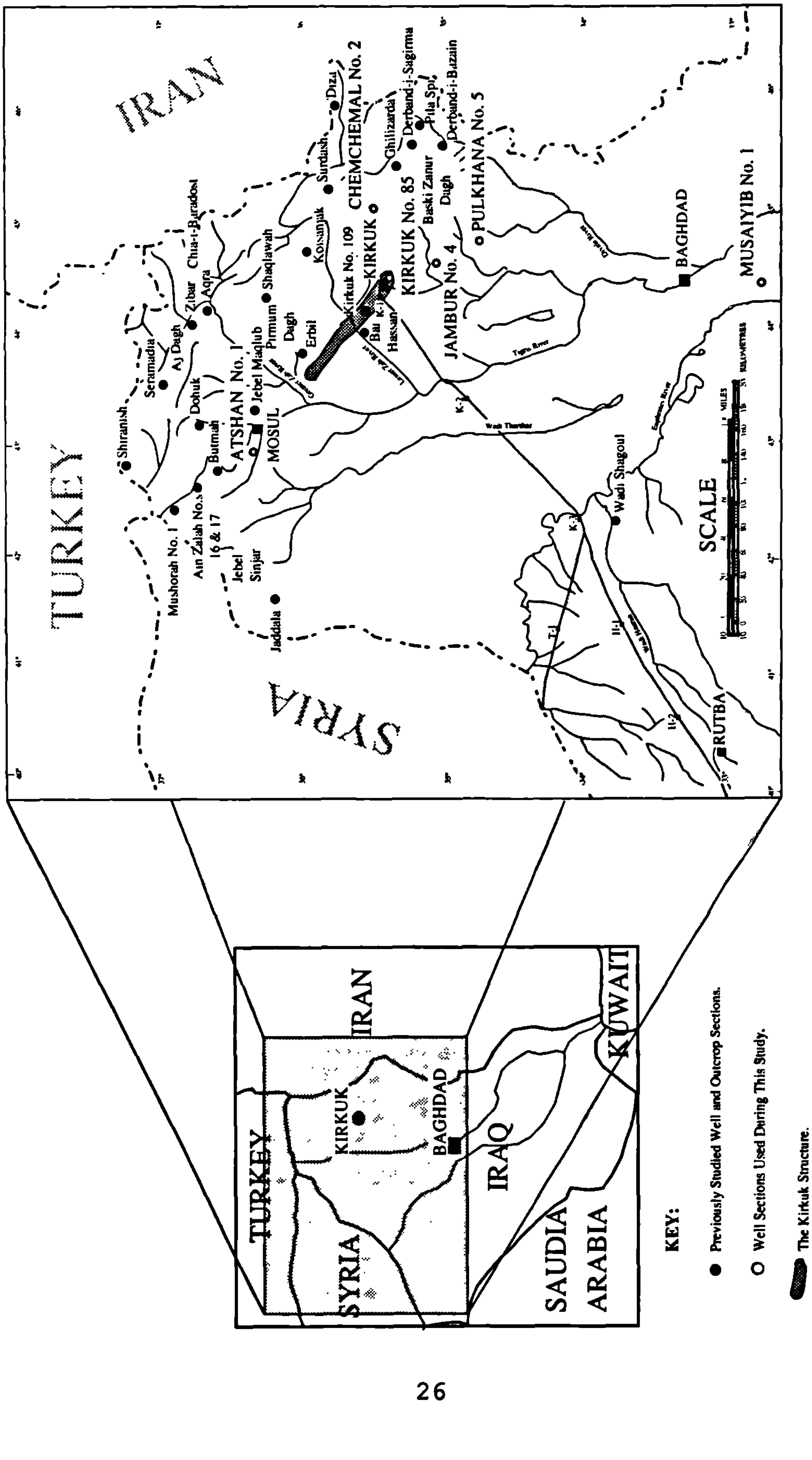


Figure 2.5 Location Map of Previously Studied Outcrop and Well sections, and the Well Sections used during this Present Study for the Mid to Late Eocene Time Interval.

2.0 General Geology

Al-Naquib (1960) has studied the Jaddala Formation in detail, from the Injana, Pulkhana, Jambur, Bai Hassan and Baba areas of Iraq:

In the Injana area he found that the Jaddala Formation comprises 250 metres (820 feet) of marly limestone and marls. The limestones are white to grey in colour and variably marly and contain planktonic foraminifera, but the marls are brown in colour and are poorly fossiliferous. The thickness of the Jaddala Formation here is the average figure for the Jaddala Formation over a wide area.

In the Pulkhana area the Jaddala Formation is 296 metres (970 feet) thick and comprises a sequence of brown to grey marly globigerinid limestones. Glauconite occurs in small grains in a few horizons and may indicate local intraformational breaks in sedimentation. The fauna within the Jaddala Formation is essentially globigerinid one however, bryozoa and lamellibranchs may also occur. The lower 143 metres (470 feet) of the Jaddala Formation at Pulkhana is Mid Eocene in age, and the rest is Late Eocene in age. The Jaddala Formation at Pulkhana rests directly and unconformably on the Aaliji/ Kolosh Formation(s).

In the Bai Hassan and Jambur areas, the base of the sequence is not seen, but lithologically the sequence recorded is very similar to those described in the Injana and Pulkhana areas.

To the north of the Baba area of the Kirkuk structure, the Jaddala Formation in I.P.C. Well K109 (Lat. 35° 33' 08' N, Long. 44° 18' 55'' E) is in fault contact with the overlying Sheikh Alas Limestone Formation. The Jaddala Formation here is 198 metres (650 feet) thick and comprises a globigerinal limestone succession, with subsiduary and very thin Avanah Limestone tongues. The upper 40 metres 130 feet of the sequence is of Late Eocene age. The lower 159 metres (520 feet) of the sequence has been determined as Mid Eocene in age and contains two faunas:

1. A globigerinal fauna of the Jaddala Formation.
2. A nummulitic fauna of the Avanah Limestone Formation, in the middle 18 metres (60 feet) of this part of the sequence.

Karim & Barlett (1979) re-interpreted the age of the upper 22 metres (73 feet) of the Jaddala formation on the northern limb of the Jebel Gaulat area (Zerwan village wadi) of northwest Iraq, based on planktonic foraminifera from only three samples. They assigned two samples to the Mid Eocene based on the globigerinal fauna they contain. Karim & Barlett (1979) also correlated these faunas to the *Globigerapsis kugleri* zone (P11) of Bolli (1957b), Berggren (1969a,b), Berggren *et al.* (1972), Berggren *et al.* (1974) and with the *Globorotalia bullbrooki* zone (P10/ P11) of Beckmann *et al.* (1969) and Postuma (1971). These zones are assigned to the Mid Eocene (Lower - Middle Lutetian). The third and uppermost sample yielded a mixed fauna of reworked Mid Eocene and Oligocene planktonic foraminifers. This globigerinal fauna notably contains *Globigerina cipreoensis angustiumbilicata, G. ampliapertura, Globorotalia opima opima* which are considered to be of Oligocene age (upper part of planktonic zone N 1).

El-Dawoody & Elewi (1984) studied the calcareous nannofossils, particularly discoasters, from the Jaddala Formation at latitude 36° 23' 18'' N and longitude 41° 43' 24'' E on the northern limb of the Sinjar anticline, near Kersi village, in the Jebel Sinjar area of northwest Iraq. The total thickness of the Jaddala Formation here is 212 metres (707 feet) and they divided the formation into 15 beds and 3 members. Ninety samples were collected and analysed for their nannofossil component and 6 nannoplankton zones were recognised based on Proto Decima (1975). These are arranged as follows:

6 - *Discoaster saipanensis* zone (NP17)
5 - *Reticulofenestra umbilica* zone (NP16)
4 - *Discoaster tani nodifer* zone (NP16)
3 - *Nannotetrina fulgens* zone (NP15)
2 - *Discoaster sublodoensis* zone (NP14)
1 - *Discoaster lodoensis* zone (NP13)

This zonation scheme is dealt with in more detail in chapter 6.0 Biostratigraphy.

Al-Hashimi and Amer (1986), studied planktonic and benthonic foraminifera from the top 4.5 metres (15 feet) of the Jaddala Formation, and assigned it to the Late Eocene or Early Oligocene *Globorotalia cerroazulensis* Zone (Upper P16/ P17). Al-Hashimi and Amer also correlated the *Globorotalia cerroazulensis* Zone (Upper P16/ P17) with other parts of the world including: the *Globorotalia cerroazulensis* Zone of Trinidad (Bolli, 1957, 1966, 1970) and Italy (Baumann, 1970), the *Globorotalia corpulenta* Zone (P.15 - P.17) of Syria (Bolli & Krasheninnikov, 1977), the upper part of the *Globigerina gortanii gortanii/ Globorotalia (Turborotalia) centralis* Zone (P.17) of tropical regions (Blow 1969, 1979).

Distribution: The Jaddala Formation is widespread in Iraq, it occurs in many wells in the I.P.C. and M.P.C. areas, and occurs in surface outcrop in various sections in the Jebel Sinjar and in the Azkand section on the southern dome of the Qarah Chauq Dagh. The Jaddala Formation has not been found in the southern area of Iraq as yet, probably because the area of known occurrence in both wells and outcrops is close proximity to the Arabian Shield. There is but little doubt though, that the Jaddala Formation occurs to the east of the eastern-most wells in the southern area.

2.3.2 Avanah Limestone Formation:

Type Section: I.P.C. Well K116 (Lat. 35° 47' 28 . 99" N, Long. 43° 59' 06 . 34" E) between drilled depths 672 metres (2205 feet) and 884 metres (2899 feet), on the Avanah dome of the Kirkuk structure.

Author(s): Mc.Ginty (1953).

Synonyms: "FEM" of Daniel (1954), "FEU" of Daniel (1954), "Middle Eocene shoal facies" of van Bellen (1956), "Upper Eocene shoal facies" van Bellen (1956) and part the "Qarah Chauq Group" of Barber (1948).

Lithological Characteristics/ Thickness: The Avanah Limestone Formation comprises limestones, generally dolomitized and recrystallised, shoal facies, with occasional intercalations of dolomitized lagoonal limestones (Pila Spi Limestone Formation). The top part is less dolomitized and recrystallised than the part below the drilled depth of 730 metres (2394 feet). Overall the Avanah Limestone Formation is 212 metres (694 feet) thick in the type section.

Al-Naquib (1960) also reported rare grey-green marl streaks in the partly dolomitized limestones of the Avanah Limestone Formation from the same type locality.

Basal Contact: The Avanah Limestone Formation unconformably overlies, perhaps erosively, the silty limestone of the Khurmala Limestone Formation (more detail of this contact is discussed in the Khurmala Limestone Formation above).

Top Contact: The Avanah Limestone Formation is unconformably overlain by the Lower Fars Formation. The unconformity is marked by the Basal Fars Conglomerate.

Biostratigraphical Data: The Avanah Limestone Formation dated using benthonic foraminifera and is undoubtedly "Mid" to "Late" Eocene in age, however in rare cases it is possible that part of the "Early" Eocene may be represented as well. The limit between the Late and Mid Eocene at the type locality and occurs between the drilled depths of 730 metres (2394 feet) and 744 metres (2439 feet). This interval cannot be dated accurately due to strong dolomitization of the limestones. The fauna recorded from the Avanah Limestone Formation at the type section consists mainly of benthonic foraminifera, but rare corals have also been noted by Al-Naquib (1960) in the type section.

Al-Naquib (1960) also studied the Avanah Limestone Formation in the Khurmala dome area. The Avanah Limestone Formation here is 168 metres (550 feet) thick, strongly recrystallised and dolomitized. He also recorded a benthonic foraminiferal assemblage. Al-Naquib (1960) also studied the Avanah Limestone Formation from the middle 60 feet (18 metres) of the Jaddala Formation at the I.P.C. Well K109 (Lat. 35° 33' 08'' N, Long. 44° 08' 55'' E). These very thin limestones yielded a mixed benthonic planktonic foraminiferal assemblage.

Distribution: According to well data the Avanah Limestone Formation occurs in a belt trending roughly N-135°-E from M.P.C. Well Mushorah No.1 in the northwest to Baski Zanur Dagh in the southeast, where it crops out. The belt is 32 - 40 kilometres (20 - 25 miles) wide. The Avanah Limestone Formation also occurs in water wells near the I.P.C. pipeline station H-1 and in Wadi Shagoul.

2.3.3 Pila Spi Limestone Formation:

Type Section: Outcrop section at Pila Spi (Lat. 35° 12' 30''N, Long. 44° 11' 00'' E).

Supplementary Type Section: Outcrop section at Kashti on the Baranand Dagh near Pila Spi (Lat. 35° 06' 35'' N, Long. 45° 42' 10'' E). This supplementary type section was chosen because the Pila Spi Limestone Formation at the type section is practically unfossiliferous due to strong recrystallisation and dolomitization. In addition, an artifical lake being constructed in the late 1950's at Derband-i-Khan would eventually submerge the type section.

Author(s): The type section was originally described by Lees (1930) but this later emended by Wetzel (1947). Finally, the Pila Spi Limestone Formation was emended a second time by van Bellen (1957).

Basal Contact: The Pila Spi Limestone Formation rests unconformably on the Gercüş Red Beds Formation at the type locality. This contact is sometimes gradational through interfingering and is sometimes marked by a conglomerate. This indicates that the two formations to some extent are time equivalents.

At the supplementary type section the Pila Spi Limestone Formation overlies the Kolosh Clastics Formation which shows intercalations of the Sinjar Limestone Formation; the contact is unconformable and is marked by a conglomerate.

Top Contact: The Pila Spi Limestone Formation is unconformably overlain by the Lower Fars Formation at both the type outcrop section and at the supplementary outcrop section.

Lithological Characteristics/ Thickness: The Pila Spi Limestone Formation comprises well-bedded limestones which contain localized bitumen impregnations at outcrop. Where the bitumen impregnations are absent the limestone is white and buff in colour. The upper 57 metres (186 feet) of the Pila Spi Limestone Formation comprises well-bedded bituminous limestones which contain bands of pale green marl or white chalky marl with buckled bedding planes. Towards the top of the Pila Spi Limestone Formation, bands of buff brown chert nodules occur. The lower 28 metres (91 feet) of the Pila Spi Limestone Formation comprise well-bedded limestones which are hard and chalky white in appearance, they are also porous or vitreous or bituminous. The limestone is also poorly fossiliferous, though it contains algal and shell sections preserved in calcite. Overall the Pila Spi Limestone Formation is 85 metres (277 feet) thick at the type section.

The Pila Spi Limestone Formation at the supplementary type section comprises dolomitic, chalky limestone with a few less dolomitized bands with rare chert intercalations, traces of subooliths and rare concentrations of gastropod debris. The Pila Spi Limestone in the supplementary type section is 189 metres (620 feet) thick.

Biostratigraphical Data: The Pila Spi Limestone Formation at the type section and the supplementary type section both contain benthonic foraminifera. However, at the supplementary outcrop section the Pila Spi Limestone Formation is less recrystallised and dolomitized, and therefore the fossil remains are more recognisable. The Pila Spi Limestone Formation in the supplementary section contains two more fossiliferous bands:

Band 1. Occurs between 104 metres (340 feet) and 122 metres (400 feet) above the base of the Pila Spi Limestone Formation.

Band 2. Occurs about 15 metres (50 feet) above Band 1 and contains essentially the same benthonic foraminiferal assemblage.

The remains of molluscs, echinoids and algae have also been recorded from the Pila Spi Limestone from the various localities.

The Pila Spi Limestone Formation has been dated as "Mid" and/or "Late" Eocene in age. This age has been accepted at the supplementary outcrop section as interfingering occurs with the Tuqaiyid beds, which are part of the Dammam Limestone Formation and have been dated as a definite Mid and Late Eocene shoal fauna. Also, the Tuqaiyid fauna is similar to that fauna contained in the fossiliferous bands of the Pila Spi Limestone Formation at the supplementary type section.

Youkhana and Sissakian (1986), studied the Pila Spi Formation in the Shaqlawa - Quwaisjag area of North Iraq and identified benthonic foraminifera to which they tentatively assigned a Late Eocene age.

Al-Ameri and Farook (1986), studied palynomorphs from the Pila Spi Limestone Formation near Salahaddin, Erbil, North Iraq. They recorded algal remains, dinoflagelates, trilete spores and angiosperm pollen. They dated the Pila Spi Limestone Formation based on the palynomorphs and assigned a Mid to earliest Late

Eocene age to the formation. They also used the palynomorphs to correlated the Pila Spi Limestone Formation with equivalent planktonic foraminiferal zones: the *Truncorotaloides rohri* Zone to the *Globigerina semiinvoluta* Zone of Stainforth *et al.* 1975, and the *Truncorotaloides rohri* Zone (P14) to the *Globigerinatheca semiinvoluta* Zone (P15) of Blow (1969). In addition, the palynomorphs studied in Iraq are correlated with similar work by Wingate (1983) on the Elk Formation, near Elko, Nevada, U.S.A. and with work by Stover & Partridge (1982) on the Werillup Formation, in Western Autralia.

Distribution: The Pila Spi Limestone Formation also occurs at the following localities: Shiranish, Ser Amadia, Aqra, Pirmum Dagh, Koi Sanjak, Surdash, Ghilizarda, Aj Dagh, I.P.C. Well Chemchemal No.2, Jebel Maqlub and Dohuk. In Shiranish and a number of these other neighbouring sections the "Late" Oligocene Anah Limestone Formation unconformably overlies the Pila Spi Limestone Formation, although the contact is very much obscured in the field due to recrystallisation and dolomitization, but differences in lithology are clearly visible on thin section analysis. The Pila Spi Limestone Formation passes laterally southwestward, with interfingering, into the Avanah Limestone Formation. Interfingering also typically occurs between the Pila Spi Limestone Formation and limestones containing *Nummulites bayhariensis* Checchia Rispoli on the Baski Zanur Dagh, at Qishlaq Qafur Agha gorge.

2.3.4 Gercüş Red Beds Formation:

Type Section: Outcrop section at Gercüş, 20 kilometres (12.5 miles) north of Midyat in Turkey.

Supplementary Type Section: Outcrop section at Dohuk (between Lat. 36° 52' 52" N, Long. 43° 00' 50" E, and Lat. 36° 52' 27" N, Long. 43° 00' 36" E) in Iraq.

Author(s): Type Section: Maxson (1936), in an unpublished report for Petrol Grubu, Turkey (*fide* S.W. Tromp, 1941).

Supplementary Type Section: Wetzel (1954).

Synonyms: "Purple shale group" of Richardson (1941), and with part of the "Série d'Imam Hassan" of Nicolesco (1933).

Lithological Characteristics/ Thickness: The Gercüş Red Beds Formation at the supplementary type section comprises generally red and purple shales, mudstones, and marls containing sandy, gritty and pebbly components. The Gercüş Red Beds Formation also contains some soft pebbly sandstones and conglomerates, lenticles of gypsum (especially towards the top), rock salt occurs sporadically, and rare lignite in sandstone near the base. The lower 259 metres (850 feet) consists of variegated marls, silstones, sandstones and conglomerates, still predominantly red in colour but also with green coloured material. The pebbles of the conglomerate mostly consist of the same green rock, chert and flint making up the Kolosh Formation. This originated from the thrust sheet or nappe which was uplifted in the northeast during Late Cretaceous - Eocene times. Some conglomerates show pebbles of older rock types. In the Kokoyi section the pebbles consist of Early Cretaceous Sinjar Limestone and a beige, much broken flint which cannot be attributed to any formation, nor does it seem to belong to the sequence of the Derband-i-Bazian section. The same flint occurs in Early Cretaceous pebbles and the usual green rock, chert and flint pebbles. In Nador North section pebbles of Jurassic limestone, Mesozoic oolitic limestone, *Oligostegina*-limestone and the broken beige flint are noted. Overall the Gercüş Red Beds Formation is 838 metres (2750 feet) thick in the supplementary type section in Iraq.

Basal Contact: The Gercüş Red Beds Formation rests upon the Kolosh Clastics Formation probably unconformably, and is marked by a conglomerate at the supplementary type section. This contact is discussed further under the Kolosh Clastics Formation above.

Top Contact: The Pila Spi Limestone Formation overlies the Gercüş Red Beds Formation. In the supplementary type section lenses of gypsum separate the two formations, which may indicate a possible unconformity.

Biostratigraphical Data: The Gercüş Red Beds Formation in the supplementary type section contains few fossils, only radiolaria and occasional ostracods have been recorded. The Gercüş Red Beds Formation is possibly "Mid" Eocene in age, but this dating is controversial. In many places interfingering takes place with the overlying Pila Spi Formation as at Derband-i-Sagirma, Surdash and I.P.C. Well Chemchemal

No.2. This indicates a roughly similar age as the Pila Spi Limestone Formation, that is of "Mid" Eocene age. In other places the Gercüş Formation is separated from the Pila Spi Limestone Formation by a conglomerate, as at Shaqlawah. Also, a possible unconformity is marked by gypsum lenses at the supplementary type section as stated earlier. The last two cases indicate a pre-Pila Spi Limestone age for the Gercüş Formation. Although evidence for a definite Early Eocene age is lacking at the supplementary outcrop section the Gercüş Red Beds Formation shows rare, reworked "Early" Eocene foraminifera including *Dorothina subglabra* (Gümbel) and *Globorotalia aragonensis* Nuttall. In Iraq as elsewhere in the Middle East there is evidence of a persistent break between the lastest "Early" Eocene and the earliest "Mid" Eocene. For these reasons a tentative "Mid" Eocene age can be adopted for the Gercüş Red Beds Formation where a unconformity can be recognised, although the evidence is far from conclusive.

Youkhana and Sissakian (1986), studied the Gercüş Formation in the Shaqlawa - Quwaisjag area of North Iraq. They identified a mixed planktonic and benthonic foraminiferal assemblage which they assigned an Early to earliest Late Eocene age.

Distribution: The Gercüş Red Beds Formation occurs throughout the Kurdistan mountain zone, west and southwest of a line running roughly from Shiranish, via the Chia-i-Baradost to Pila Spi, and is recorded in the I.P.C. Well Chemchemal No.2 and M.P.C. Wells on the Ain Zalah and Mushorah structures. The northern limit of the Gercüş Red Beds Formation can be located in the field along the western slopes of the Chia-i-Baradost in a section from Dar-e-Tesu via Diza to Zibar. At Dar-e-Tesu the Gercüş Red Beds Formation is 88 metres (290 feet) thick and is sandwiched between Palaeocene strata and Mid/ Late Eocene Pila Spi Limestone Formation. Towards the northwest at Diza the Gercüş Red Beds Formation is only 24 metres (80 feet) thick and occurs between Late Cretaceous and Miocene strata. At the Zibar section, at the furthest northwest end of the exposures, the Gercüş Red Beds Formation is absent and Miocene strata rest directly and unconformably on the Late Cretaceous. At most other localities in Kurdistan the northern and eastern limits of the convergent wedge of the Gercüş Red Beds Formation are hidden beneath the large overthrust sheets. Towards the west, the lithological characteristics of the Gercüş Red Beds Formation are poorly developed partly due to interfingering with marls, and partly because the formation occurs in wells so that the characteristic red colouration of the formation is ill-developed as the rocks are in a reduced state.

As part of their microfacies studies for the Tertiary of Iraq, Al-Hashimi and Amer (1985) recognised 7 planktonic foraminiferal zones and 4 benthonic foraminiferal zones for the Mid to Late Eocene formations mentioned above based on sub-surface and outcrop samples from a wide area of northern Iraq (see Figure 2.6).

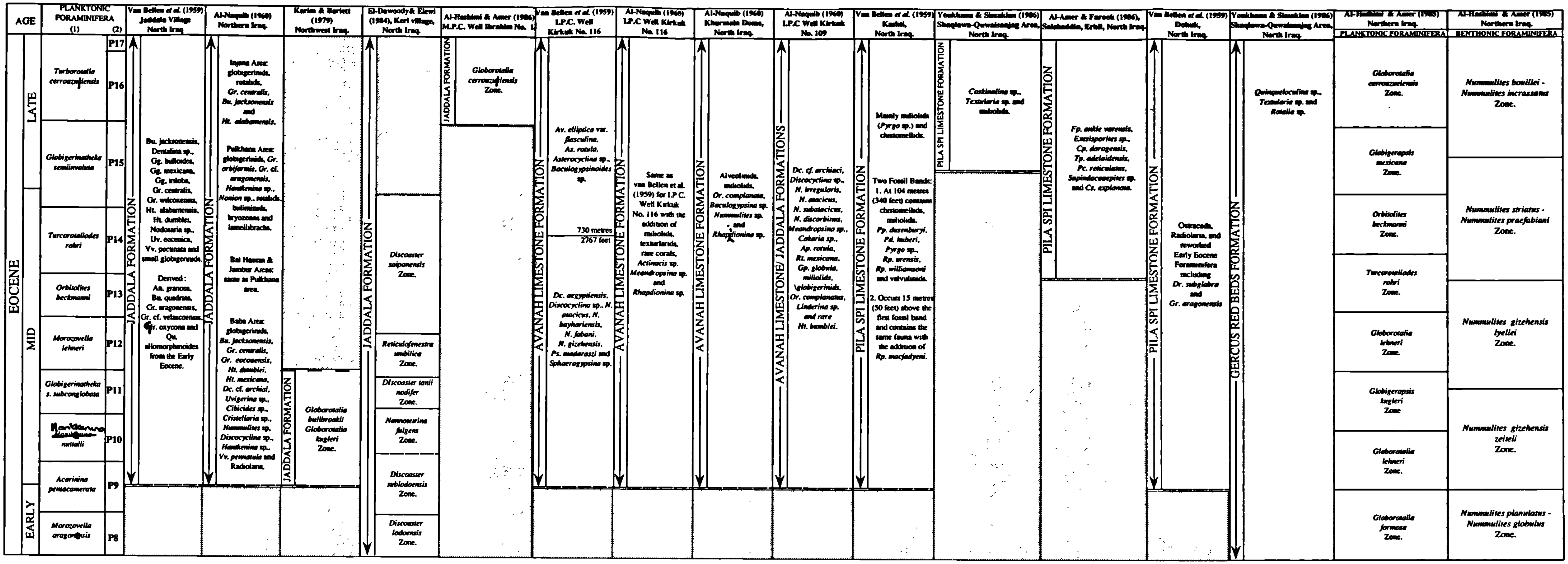
2.3.5 Studied Well Sections:

The Jaddala, Avanah Limestone, Pila Spi Limestone and the Gercüş Red Beds Formations were encountered in Atshan No. 1, Jambur No. 4, Kirkuk No. 85, Musaiyib No. 1 and Pulkhana No. 5 well sections in this study. These well sections are described below, but more information on the lithologies making up these formations can be seen in the well logs in Appendix A:

Atshan No. 1: The Jaddala Formation interfingers with the Avanah Limestone Formation and is 132.6 metres (442 feet) thick. The Jaddala/ Avanah Limestone is underlain unconformably by the Aaliji/ Khurmala Limestone Formations and is unconformably overlain by the Euphrates Limestone Formation.

Chemchemal No. 2: The Gercüş Red Beds Formation is 15 metres (50 feet) thick. The Gercüş Red Beds Formation rests probably unconformably upon the Khurmala Limestone Formation, and the Gercüş Red Beds Formation in turn is conformably overlain by the Pila Spi Limestone Formation. The Pila Spi Limestone Formation in this section is 228.6 metres (762 feet) thick and is unconformably overlain by the Lower Fars (Transition Beds and Basal Conglomerate).

Jambur No. 4: The top of the Jaddala Formation is unconformably overlain by the Serikagni Formation according to well logs. However this is disputed in this study



KEY:

Planktonic Foraminifera:	Benthonic Foraminifera:
Gb. Globigerapsis	*An. Anomaliniodes*
Gg. Globigerina	*Ap. Amphistegina*
Gr. Globorotalia	*As. Asterigerina*
Ht. Hantkenina	*Av. Alveolina*
	Bu. Bulimina
Spore Species:	*Dc. Discocyclina*
Cp. Cicatricosporites	*Dn. Dictyoconus*
Cs. Chytroeisphaeraidae	*Dr. Dorithina*
Fp. Faveodiporites	*Gp. Gypsina*
Pc. Polycolpites	*N. Nummulites*
Tp. Tricolporites	*Or. Orbitolites*
	Pd. Praerhapidionina
	Pp. Peneroplis
NOT ZONED	*Ps. Pellatispira*
HIATUS	*Rp. Rhapidionina*
	Rt. Rotalia
	Vv. Valvulina

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & Premoli Silva (1973) and Bolli & Saunders in Perch-Nielsen *et al.* (1985).

(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvering (1974).

Figure 2.6 Previous Biostratigraphic Work for the Early to Late Eocene Succession of Northern Iraq.

as it is believed that the Serikagni Formation rests unconformably upon the Palani Formation. The reasons for this are explained in Chapter 6.0 Biostratigraphy and are illustrated in Appendix A with the well log, data sheet, range chart and abundance diagram.

Kirkuk No. 85: The top of the Jaddala Formation was sampled and it is unconformably overlain by the Palani Formation.

Musaiyib No. 1: The top of the Jaddala Formation was sampled, and it is again unconformably overlain by the Palani Formation.

Pulkhana No. 5: The Jaddala Formation is 296 metres (984 feet) thick, and is unconformably lies upon the Aaliji Formation and the Jaddala Formation in turn unconformably overlain by the Serikagni Formation. However, in this section it is believed that the upper part of the Jaddala Formation is really the Palani Formation. The reasoning behind this is explained in Chapter 6.0 Biostratigraphy and is illustrated in Appendix A using well log, data sheet, range chart and abundance diagram information.

2.3.6 Regional Lateral Equivalents:

Following Beydoun (1989), the Jaddala, Avanah Limestone, Pila Spi Limestone and the Gercüş Red Beds Formations can be correlated with lateral equivalents in other Middle Eastern countries. In southeastern Turkey this group of formations can be correlated with the Hoya Formation. In southwestern Iran correlation can be made parts of the Pabdeh, Shahbazan and Jahrum Formations, and with the Dammam Limestone Formation of Southern Iraq, Kuwait, Saudi Arabia, Qatar and Abu Dhabi. Correlations can also be made with the Dammam Limestone Formation and the Pabdeh Formation from the mountains in the east of the United Arab Emirates (U.A.E.). This set of formations is also equivalent to the Jaddala, Midyat, Sinjar Limestone and Tyron Formations and the Araq Flint member in Syria and the Sara and Maan Formations in Jordan. This set of formations also has unnamed equivalents in Lebanon coastal region and is also equivalent to the upper part of the Shephela Group (Sara Formation) in Israel.

2.3.7 Sedimentology and Depositional History:

The sedimentology and depositional history for this time interval is based upon van Bellen *et al.* (1959), Dunnington (1958), Buday (1980) and Al-Hashimi and Amer (1986) and Beydoun (1989), and is illustrated in Figure 2.7. During the Early Eocene widespread regression occurred in response to orogenic movements during the Van phase of the Laramide orogeny. This led to widespread erosion over Iraq followed by re-establishment of marine conditions with a marine transgression in the late Early Eocene. This resulted in the unconformable relationship between the Mid to Late Eocene sediments and the underlying Palaeocene to Early Eocene succession, and is usually marked by a glauconite concentration. The lithostratigraphic pattern during the Mid to Late Eocene is relatively simple compared to that of the Palaeocene to Early Eocene in this area. Sedimentation began anew in the broad linear northwest-southeast basin, which had virtually ceased accumulating clastics from the topographic high towards the northeast. On the northern margin of the basin nummulitic Avanah Limestone was deposited as a reef, acting as a partial barrier behind which lagoonal limestones of the Pila Spi Limestone Formation accumulated. The only clastics shed into the former flysch trough are the Gercüş Red Beds which probably represent alluvial fan deposits. South of the nummulitic reef limestones, globigerinal marly, limestones of the Jaddala Formation were deposited in open marine conditions. The sediments of the Jaddala Formation are thickest on the northern margin of the basin, and then thin towards the centre of the basin and the thicken again towards the Ga'ara High. Locally the sediments of the Jaddala Formation have abundant planktonic foraminiferal faunas, are organic rich, and were deposited in anaerobic condition.

Majid and Veizer (1986) suggest a similar model based upon the work of Read (1985), with the formation of a carbonate ramp after the re-establishment of marine conditions. The carbonate ramp evolved basinward of the previous Palaeocene to Early Eocene cycle in the broad basin and developed restricted lagoonal carbonates

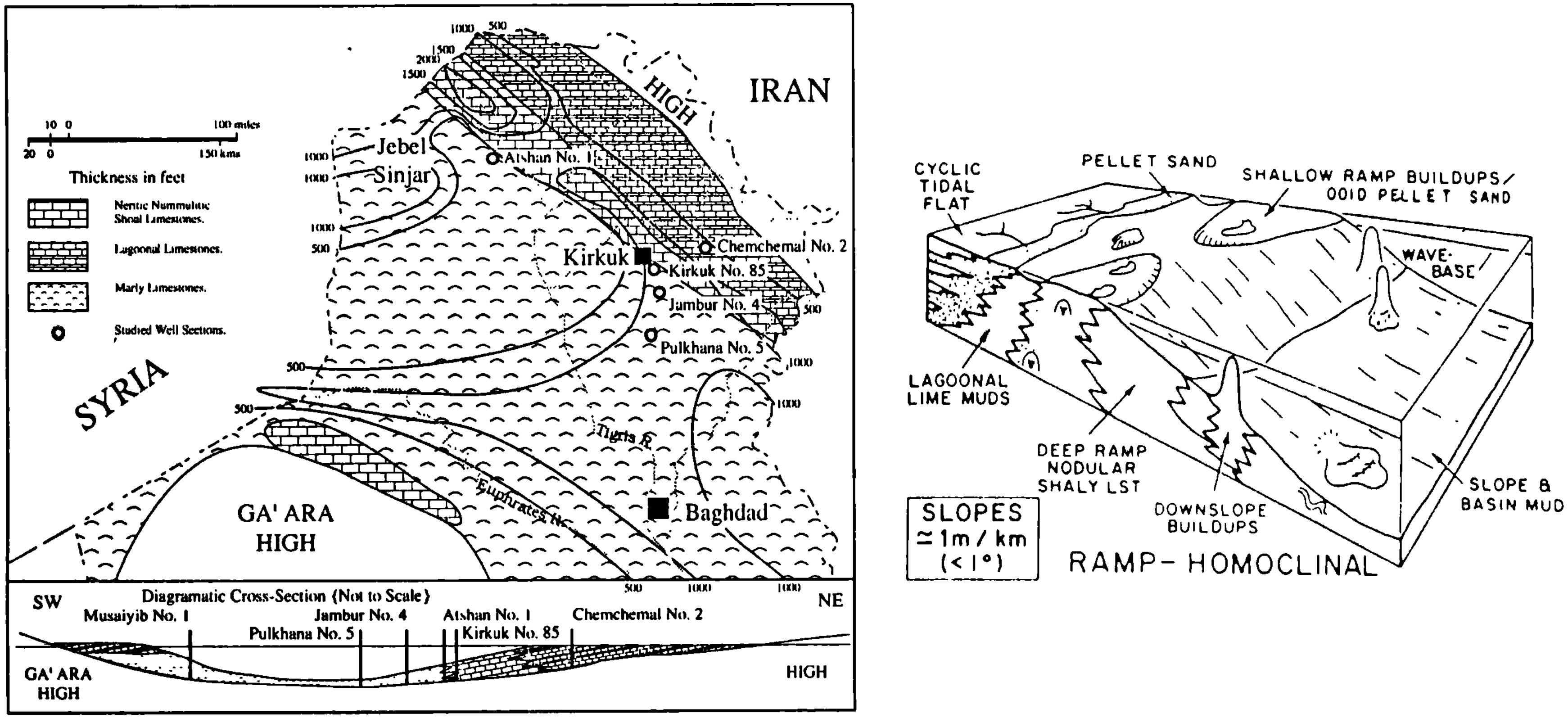


Figure 2.7. Isopach-Facies Map & Model for the Mid-Late Eocene of Northern Iraq (Partly modified after Dunnington, 1958 & Read, 1985 respectively).

of the Pila Spi Limestone Formation behind the Avanah Limestone bioherms. This sediment deposition model is illustrated in Figure 2.7 along with a map of the distribution of formations in the Mid to Late Eocene time interval. Majid and Veizer (1986) preferred the term bioherm to reef to describe the Avanah limestones as the limestone lack frame-building organisms in their growth positions. They also studied the geochemical nature of the nearshore and offshore basinal sediments and found that the nearshore sediments had low sodium and strotium contents as well as light $\delta^{18}O$ and $\delta^{13}C$. In contrast the basinal sediments have the opposite attributes and foreshore deposits had intermediate sodium, strotium and oxygen and carbon contents. Majid and Veizer (1986) explained these results by the fact that nearshore sediments in the nearshore area were deposited in water with a marked meteoric aspect while the basinal sediments were laid down in water with a similar composition of present day seawater. The foreslope sediments were deposited in waters with intermediate compositions between meteoric water and seawater. This relatively simple model for this group of formations is complicated, as interfingering and intergrading occurs between these Jaddala, Avanah Limestone, Pila Spi Limestone and Gercüş Red Beds formations reflecting them effectiveness of the "reef"-type (bioherm) limestones as a barrier. The relationships between the Jaddala, Avanah Limestone, Pila Spi Limestone and the Gercüş Red Beds Formations is complicated due to interfingering and later grading of the formations caused by the ineffectiveness of the nummulitic reef limestones as a barrier to sea level changes. The basin geometry is also complicated by the appearance of troughs and topographic highs within the basin. The troughs are reactivated Late Cretaceous troughs and are located in the Jebel Sinjar area, in the Euphrates Valley through Anah, northwest of Kirkuk and north of Baghdad.

(1). **Jebel Sinjar:** Two troughs are located in the Jebel Sinjar area. The first occurs to the north of Jebel Sinjar and trends northwest-southeast. The trough is relatively narrow, steep sided and accumulated approximately 300 metres (1000 feet) of Avanah and Pila Spi limestones. The second trough occurs south of Jebel Sinjar and trends east-west. This trough is relatively narrow, shallow and gently sided and accumulated approximately 150 metres (500 feet) of globigerinal limestone of the Aaliji Formation.

(2) **Euphrates Valley:** One elongate east-west trough is located in this area and is

sometimes referred to as the Anah Trough. The sides of the trough are steep but it is relatively shallow and accumulated approximately (150 metres) 500 feet of globigerinid limestones. The sediments deposited in this trough are most likely derived from the Ga'ara High immediately to the south.

(3) **Kirkuk:** This trough occurs northwest of Kirkuk and is elongate, relatively shallow and asymmetrical, being steeper side on it southern margin than its northern margin. The trough accumulated approximately 150 metres (500 feet) of Avanah and Pila Spi limestones.

(4) **Baghdad:** This trough occurs north of Baghdad and runs northwards into the Kirkuk trough, and westward into the Anah trough so that all together they form a Y-shaped outline in plan view. The Baghdad trough itself is a relatively broad, gentle sided and shallow, accumulating approximately 75 metres (250 feet) of globigerinid limestones.

The topographic highs within the broad basin include the Ga'ara High and two small elongate highs to the northeast of Qaiyarah. The Ga'ara High remained active from the Palaeocene to Early Eocene and occupied an even larger area during this time interval. The Ga'ara High is located on the southwest part of the northern area of Iraq and developed a thin sequence of patchy neritic limestones on its northeastern margin. This sequence of limestones is somewhat thinner on the southern margin of the basin than those developed on the northern margin as the basin shelves more gently on the southwestern margin. Around the rest of the Ga'ara High an apron of globigerinid marly limestones was deposited. The sediments laid down around the Ga'ara High have similarities with the Avanah Limestone and Jaddala Formations from northern Iraq and with the Dammam Limestone in southern Iraq. Similar grabens and horst structures were also recognised Ibrahim (1979).

The terminal Eocene regression caused subaerial exposure of a wide area of Iraq and led to an unconformity being established between the Late Eocene and Early Oligocene. In some areas, for example north of Kirkuk, the subaerial exposure lasted much longer and Late Eocene sediments are unconformably overlain by Early Miocene sediments.

2.4 Oligocene:

The Kirkuk Group comprises the Oligocene succession and is described in detail below:

2.4.1 KIRKUK GROUP:

The Kirkuk Group was originally defined and described by van Bellen (1956) from the sequence on the Bai Hassan and Qarah Chauq Dagh structures in North Iraq. The Kirkuk Group is synonymous with parts of the "Kara Tchauq Dagh series" of Nicolesco (1933); the "Calcaire d'Asmari", the "Calcaire l'Euphrate" and the "Série d'Asmari" of Macovei (1938) and the "Qarah Chauq Group" of Barber (1948).
The Kirkuk Group comprises nine formations which are arranged as follows:

BACK-REEF	FORE-REEF	OPEN SEA	OLIGOCENE
Anah Limestone	Azkand Limestone	Ibrahim	"Late"
Bajawan Limestone	Baba Limestone	Tarjil	"Mid"
Shurau Limestone	Sheik Alas Limestone	Palani	"Early"

The Kirkuk Group forms a sequence of reef-controlled sediments of Oligocene age, in which three separate "cycles" can be distinguished.

The Ibrahim Formation did not appear in the original definition of the Kirkuk Group but its presence was anticipated:

> "*...as yet undiscovered or unidentified off-shore equivalent of the Anah-Azkand Limestone Formation...*" van Bellen (1956 p.261).

The formations of the Kirkuk Group are individually described in stratigraphic order below and a map showing the location of outcrop and well sections used in previous studies to describe the formations in this time-interval can be seen in Figure 2.8. In addition, a summary diagram of the biostratigraphic data from all these previous works

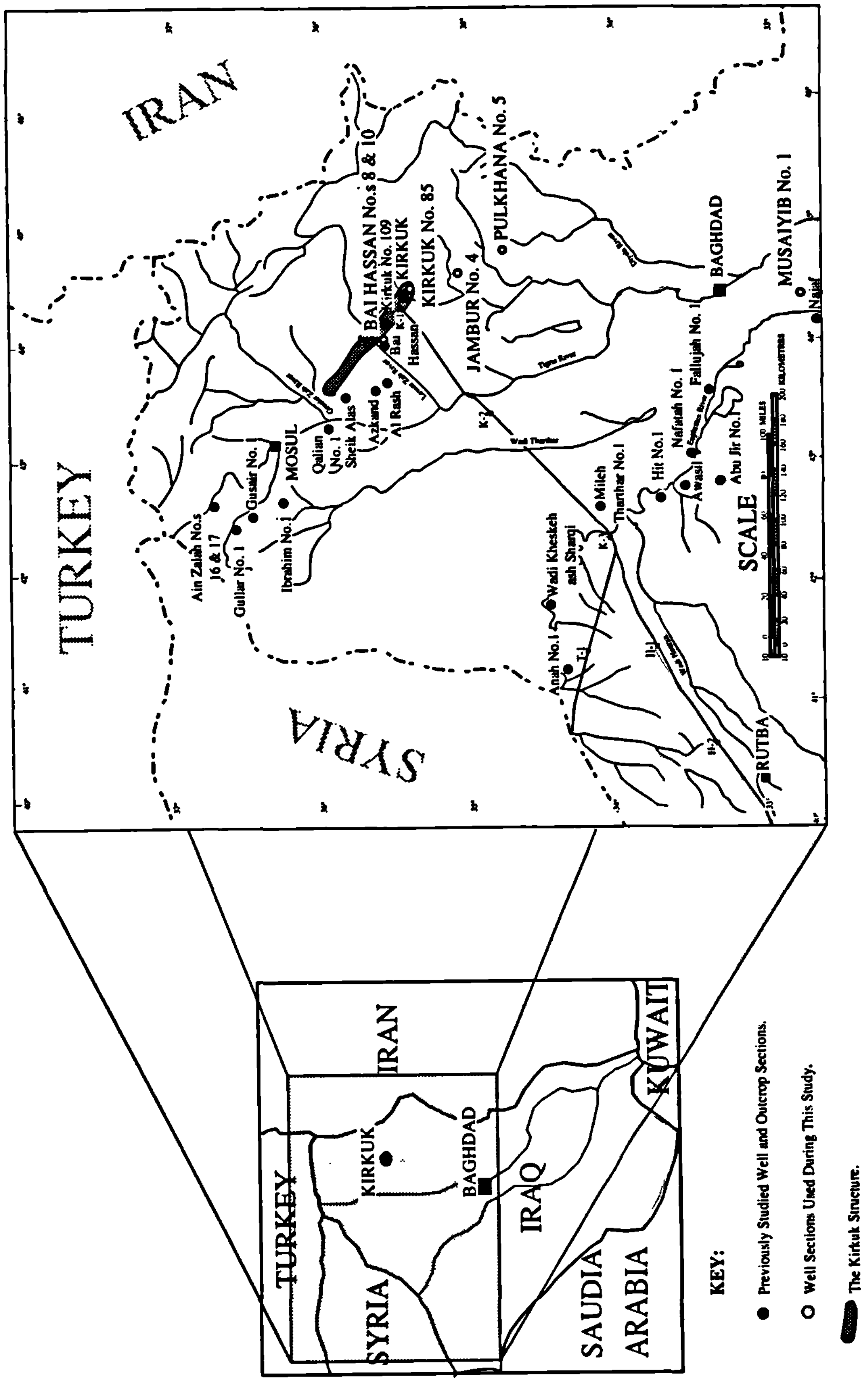


Figure 2.8 Location Map of Previously Studied Outcrop and Well sections, and the Well Sections used during this Present Study for the Oligocene Time Interval.

can be seen in Figure 2.9.

2.4.2 Early Oligocene

2.4.2(i) Palani Formation:

Type Section: I.P.C. Well Kirkuk No.85 (Lat. 35° 26' 42'' N, Long. 44° 25' 28'' E) on the Tarjil plunge of the Kirkuk structure between the drilled depths of 973 metres (3192 feet) and 1037 metres (3400 feet).

Author(s): van Bellen (1956).

Synonyms: "GO/1" of Daniel (1954) and parts of the "*Globigerina* Limestone" of Barber (1948) and the "Globigerinal Limestones and marls" of Baker (1953).

Lithological Characteristics/ Thickness: The lithology comprises a somewhat dolomitized, globigerinid, marly limestone and is 63 metres (208 feet) in drilled thickness at the type well section.

Al-Naquib (1960), described the Palani Formation in detail from the southeastern end of the Baba dome of the Kirkuk structure. The Palani Formation is 64 metres (210 feet) thick here, and on the Tarjil plunge it directly underlies the Tarjil Formation. This contact is marked by a 2 metre (7 feet) thick glauconite bed that occurs at the top of the Palani succession. The glauconite bed marks an unconformity between the "Early" and the "Mid" Oligocene "cycles". The rest of the sequence below the glauconite band comprises a globigerinid, marly limestone which is slightly dolomitized and in parts, phosphatic with fish remains. A few anhydritic nodules occur towards the middle of the sequence.

Basal Contact: The Palani Formation lies unconformably upon the Jaddala Formation at the type well section.

Top Contact: The Sheik Alas Limestone Formation conformably overlies the Palani Formation at the type well section and the contact is gradational with some interfingering. The Tarjil Formation may lie unconformably on the Palani Formation, the contact being marked by a glauconite bed.

Biostratigraphical Data: The Palani Formation is considered to be "Early" Oligocene in age in the type well section based upon the planktonic foraminifera it contains.

Al-Naquib (1960) recorded planktonic foraminifera from the Palani Formation in the

Baba Dome area of the Kirkuk Structure, which he assigned to the Early Oligocene.

Al-Hashimi and Amer (1986), in their restudy of the Ibrahim Formation from the type well section in the M.P.C. Well Ibrahim No.1, in the Mosul area of North Iraq, also studied the Palani Formation. They recorded a planktonic foraminiferal assemblage which they dated as the lowermost Early Oligocene. They also assigned the planktonic foraminiferal assemblage to the *Cassigerinella chipolensis/ Globanomalina micra* Zone (P18 and P19) of Bolli (1966). The lower boundary of the zone is characterised by the first appearance of *Cassigerinella chipolensis* (Cushman & Ponton). Both *Globigerina ciperoensis* Bolli and *Globanomalina micra* (Cole) have their last appearances in this zone. Al-Hashimi and Amer also correlate this zone with the *Cassigerinella chipolensis/ Globanomalina micra* Zone (P18 and P19) of Trinidad.

Distribution: The Palani Formation occurs in most wells on the Kirkuk structure south of the Lesser Zab river and in wells on the Bai Hassan structure. The Palani Formation crops out on the northern dome of the Qarah Chauq Dagh structure, especially at the village of Palani (Lat. 35° 49' 15"N, Long. 43° 35' 30" E), hence the name of the formation. Further north the unit is found again in M.P.C. Wells Qalian No.1 and Gussair No.1. Towards the west it occurs in M.P.C. Wells Mileh Tharthar No.1, Abu Jir No.1 and Hit No.1.

2.4.2(ii) Sheik Alas Limestone Formation:

Type Section: Outcrop section approximately 732 metres (800 yards) N-252°-E of the village of Sheik Alas (Lat. 35° 54' 38" N, Long. 43° 35' 30" E) on the northern dome of the Qarah Chauq Dagh.

Author(s): van Bellen (1960).

Synonyms: "Limestone with *Nummulites intermedius - fichteli*" of De Broeckh *et al.* (1929) and the "FO/1" of Daniel (1954), and parts of the following: the "Kara Tchauq Dagh Series" of Nicolesco (1933), the "Nummulite Limestone" and the "Qarah Chauq Group" of Barber (1948), the "Calcaire d'Asmari", the "Série d'Asmari" and possibly the "Calcaire de l'Euphrate" of Macovei (1938).

2.0 General Geology

Lithological Characteristics/ Thickness: The Sheik Alas Limestone Formation comprises dolomitic and recrystallized, generally porous and occasionally rubbly limestones, and is 85 feet (26 metres) thick at the type outcrop section.

Al-Naquib (1960), recorded the Sheik Alas Limestone Formation in the Baba dome area of the Kirkuk structure. Here the formation is 30 metres (100 feet) thick and has the same lithological characteristics as the type outcrop section above.

Basal Contact: The Sheik Alas Limestone Formation is unconformable upon Eocene shoal limestones in the type outcrop section. Elsewhere the formation may conformably cover the Palani Formation.

Top Contact: The Sheik Alas Limestone Formation is conformably overlain by the Shurau Limestone Formation. Elsewhere the Baba Limestone Formation may conformably cover the Sheik Alas Limestone Formation.

Biostratigraphical Data: The Sheik Alas Limestone Formation has been dated as Early Oligocene by the benthonic foraminifera it contains. Based upon the benthonic foraminiferal assemblage one zone was recognised which comprises the entire formation, the Nummulites Zone.

Al-Naquib (1960) in his studies on the Sheik Alas Limestone Formation in the Baba dome area of the Kirkuk structure recorded a similar fauna to that recorded at the type outcrop section with the addition of rare *Heterostegina* sp., *Operculina complanata* (Defrance) and less commonly bryozoan and anthozoan fragments.

Distribution: The Sheik Alas Limestone Formation crops out in a number of other sections on the northern dome of the Qarah Chauq Dagh. It also occurs in wells on the northeastern flank of the Bai Hassan structure and on the Kirkuk structure between the Lesser Zab river and the southern end of the Baba dome. Further north, the formation has been found in M.P.C. Well Qalian No.1, and in wells on the Ain Zalah structure. In the west it occurs in M.P.C. Wells Anah No.1, Hit No.1, Awasil No.1 and Nafatah No.1. It also occurs at surface in the Wadi Kheskeh es Sharqi.

2.4.2(iii) Shurau Limestone Formation:

Type Section: I.P.C. Well K109 (Lat. 35° 33' 08'' N, Long. 44° 08' 55'' E) and was named after Shurau village on the Baba dome of the Kirkuk structure (Lat. 35° 30' 03'' N, Long. 44° 22' 45'' E).

Author(s): van Bellen (1956).

Synonyms: With parts of the "Kara Tchauq Dagh series" of Nicolesco (1933), the "Qarah Chauq Group" and the "Miliola and reef limestones" of Barber (1948), the "Lower reef limestone" of Henson (1950), the "Calcaire d'Asmari", the "Série d'Asmari" and perhaps the "Calcaire de l'Ephrate" of Macovei (1938). The Shurau Limestone Formation is also synonymous with all of the "Lower and Middle Eocene Miliola limestone" of Henson (1950), the "Miliola limestone" of Grimsdale (1952) and the "MR/1" of Daniel (1954).

Lithological Characteristics/ Thickness: The Shurau Limestone Formation comprises 5.5 metres (18 feet) of grey, dense limestone and 13 metres (42 feet) thick unit of porous coralline limestone. Overall the Shurau Limestone Formation is 18 metres (60 feet) thick at the type section.

Basal Contact: The Shurau Limestone Formation conformably rests upon the Sheik Alas Limestone Formation at the type locality and section, but elsewhere it may lie directly on Eocene strata.

Top Contact: The Shurau Limestone Formation is transgressively overstepped by the Baba Limestone Formation at the type locality and section. The unconformity is marked by a faunal and facies change. Elsewhere, the Bajawan Limestone Formation of the "Mid" Oligocene "cycle" may cover the Shurau Limestone Formation unconformably.

Biostratigraphical Data: The Shurau Limestone Formation contains benthonic foraminifera, algae and corals which have been assigned to the Early Oligocene.

Al-Naquib (1960) described the Shurau Limestone Formation from the Baba dome area of the Kirkuk structure and recorded a similar benthonic foraminiferal, algal and coral assemblage from the porous coralline reef limestone.

Distribution: The Shurau Limestone Formation is found in a number of other wells on the Kirkuk structure, between the Lesser Zab River in the northwest and southeastern end of the Baba dome. The Shurau Limestone Formation also occurs in sections on the northern dome of the Qarah Chauq Dagh. More towards the west the Shurau Limestone Formation has been found in M.P.C. Wells Anah No.1 and Hit No.1 and in wells in the Kheskeh es Sharqi.

2.4.3 Mid Oligocene.

2.4.3(i) Tarjil Formation:

Type Section: I.P.C. Well K 85 (Lat. 35° 26' 42''N, Long. 44° 25' 28'' E) on the Tarjil plunge of the Kirkuk structure between the drilled depths of 2828 feet (848.4 metres) and 3192 feet (957.6 metres).

Author(s): van Bellen (1956).

Synonyms: "GO/2" of Daniel (1954), the "Globigerinal marls and limestones" of Baker (1948) and part of the "Qarah Chauq Group" of Barber (1948).

Lithological Characteristics/ Thickness: The Tarjil Formation comprises slightly dolomitized, globigerinid, marly limestones and is 107 metres (350 feet) thick at the type well section.

Basal Contact: The Tarjil Formation unconformably overlies the Palani Formation and the contact is marked by a glauconite concentration.

Top Contact: The Baba Limestone formation grades laterally into the Tarjil Formation and therefore is conformable. Elsewhere the Tarjil Formation is covered by the Azkand Limestone Formation or offshore equivalent of the Azkand Limestone Formation (Ibrahim Formation) unconformably. These units constitute the third "Late" Oligocene "cycle" of the Kirkuk Group.

Biostratigraphical Data: The Tarjil Formation contains small planktonic foraminifera (not yet determined) and benthonic foraminifera which have been assigned a Mid Oligocene age. The formation also contains benthonic foraminifera also recognised in the Baba Limestone Formation.

Al-Naquib (1960), studied the Tarjil Formation in the southeastern area of the Baba dome. The formation is 108 metres (360 feet) thick and consists mainly of globigerinid limestones which contain both planktonic and benthonic foraminiferal assemblages similar to those recorded at the type well section.

Distribution: The Tarjil Formation occurs in a few additional wells on the southern part of the Baba dome of the Kirkuk structure (the Tarjil plunge). The formation also occurs in one well on the southwest flank of the Bai Hassan structure and in I.P.C. Well Kor Mor No.2 towards the southeast. Northwest of the Kirkuk area the Tarjil Formation has been encountered in M.P.C. Wells Qalian No.1, Gussair No.1 and Gullar No.1. The formation is also recognised in western Iraq in M.P.C. Well Mileh Tharthar No. 1.

2.4.3(ii) Baba Limestone Formation:

Type Section: I.P.C. Well K 109 (Lat. 35° 33' 08'' N, Long. 44° 18' 55'' E) on the Baba dome of the Kirkuk structure, between the drilled depths of 463.5 metres (1545 feet) and 484.5 metres (1615 feet).

Author(s): van Bellen (1956).

Synonyms: "Rubbly Limestone" and the "Limestone containing *Lepidocyclina* cf. *formosa*" of De Boeckh *et al.* (1929), the "Nummulite Limestone" of Barber (1948) and the "FO/2" of Daniel (1954). The Baba Limestone Formation is also synonymous with parts of the following; the "Qarah Chauq Group" of Barber (1948), the "Kara Tchauq Dagh Series" of Nicolesco (1933) and the "Calcaire d'Asmari", the "Série d'Asmari" and possibly the "Calcaire de l'Euphrate" of Macovei (1938).

Lithological Characteristics/ Thickness: The Baba Limestone Formation comprises porous dolomitized limestone which is 20 metres (65 feet) thick in the type well section.

Basal Contact: The Baba Limestone Formation overlies the Shurau Limestone Formation unconformably at the type well section but elsewhere, the Baba Limestone Formation grades laterally into the Tarjil Formation.

Top Contact: The Baba Limestone Formation is conformably covered by the Bajawan Limestone Formation at the type well section, but elsewhere it is unconformably overlain by the Azkand Limestone or the Anah Limestone Formations.

Biostratigraphical Data: The Baba Limestone Formation contains benthonic foraminifera, corals and rare bryozoans, which have been dated as Mid Oligocene in age.

Al-Naquib (1960) studied the Baba Limestone Formation from the Baba dome area of the Kirkuk structure. The formation here is 22.5 metres (75 feet) thick and contains a similar benthonic foraminferal, coral and bryozoan assemblage which is again assigned to the Mid Oligocene.

Distribution: The Baba Limestone Formation occurs in all wells southeast of the Lesser Zab river, on the Kirkuk structure. It also occurs on the northeast flank of the Bai Hassan structure and at the surface on the northern dome of the Qarah Chauq Dagh. Northwards, the Baba Limestone Formation is found in a number of M.P.C. wells, including Qalain No.1, Gullar No.1, Gussair No.1 and wells on the Ain Zalah structure. To the west of the type locality the Baba Limestone Formation grades laterally into the Tarjil Formation, which disappears further west. The Baba Limestone Formation re-appears on the western side of the Oligocene basin in M.P.C. wells Hit No.1, Fallujah No.1 and Anah No.1. A number of surface sections along the Euphrates River, where its course is predominantly west - east, also show this formation, for example at Wadi Fuhaimi, near the village of Anah, and Wadi Kheskeh es Sharqi.

2.4.4(iii) Bajawan Limestone Formation:

Type Section: I.P.C. Well K 109 (Lat 35° 33' 08'' N, Long. 44° 18' 55'' E) between the drilled depths of 423 metres (1410 feet) and 463.5 metres (1545 feet).

Author(s): van Bellen (1956).

Synonyms: "MR/2" of Daniel (1954), and with parts of the following: the "Kara Tchauq Dagh Series" of Nicolesco (1933), the "Calcaire d'Asmari", the "Série d'Asmari", possibly the "Calcaire de l'Euphrate" of Macovei (1938), the "Qarah Chauq Group" and the "Miliola and Reef Limestone" of Barber (1948), the "Oligocene

Limestone", the "U. Oligocene Miliola Limestone", the "Oligocene Miliola Limestone" and the "Miliola Limestone" of Henson (1950).

Lithological Characteristics/ Thickness: The Bajawan Limestone Formation comprises a tight, cream-coloured, back-reef miliolid limestones, alternating with more porous partly dolomitized, rotalid-algal reef limestones with fairly abundant coral fragments. The reef beds become thicker and more abundant towards the base of the formation. Thin wisps of unfossiliferous green marl occur throughout. Overall the Bajawan Limestone Formation is 39 metres (128 feet) thick at the type well section.

Basal Contact: The Bajawan Limestone Formation rests conformably upon the Baba Limestone Formation at the type well section, although local unconformities between the two formations have been claimed by some authors.

Top Contact: The Bajawan Limestone Formation is unconformably overlain by the Lower Fars Formation at the type locality and section and is separated from it by the Basal Fars Conglomerate.

Biostratigraphical Data: The Bajawan Limestone Formation contains benthonic foraminifera, corals and bryozoans which can used to sub-divided the formation into two faunizones: the *delicata* Zone and the *kirkukensis* Zone which are assigned to the Mid Oligocene.

Al-Naquib (1960) described the Bajawan Limestone Formation from the Baba dome area of the Kirkuk structure. Here the formation is 39 metres (130 feet) thick and is lithologically similar to that above. Al-Naquib (1960) recorded a similar benthonic foraminiferal, coral and bryozoan assemblage which was again assigned to the Mid Oligocene. In the Avanah area he also found that the Bajawan Limestone Formation rests unconformably on the Jaddala Formation and in the Bai Hassan area the formation is overlain by sediments of the "Late" Oligocene "cycle", which is in turn are overlain by the Lower Fars Formation.

Distribution: The Bajawan Limestone Formation crops out on the northern dome of the Qarah Chauq Dagh. Southward and westward from the type locality and section the formation passes into fore-reef sediments of the Baba Limestone Formation, and off-shore sediments of the Tarjil Formation. The Bajawan Limestone Formation also occurs in a number of M.P.C. Wells including Qalain No.1, Ain Zalah No.9, Hit No.1, Fallujah No.1 and Anah No.1 (van Bellen *et al.*, 1959).

Late Oligocene

2.4.4(i) Ibrahim Formation:

Type Section: M.P.C. Well Ibrahim No.1 (Lat. 36° 19' 12" N, Long. 42° 38' 15" E) 1 between the drilled depths of 363 metres (1210 feet) and 418.5 metres (1395 feet) and interfingers over the upper 13.6 metres (45 feet) with the Azkand Limestone Formation.

Author(s): van Bellen (1957).

Lithological Characteristics/ Thickness: The Ibrahim Formation comprises globigerinid, marly limestone with specks of pyrite, occasional glauconite and shows slight dolomitization. It is 56.5 metres (185 feet) thick at the type well section.

Basal Contact: The Ibrahim Formation unconformably overlies the Jaddala Formation in the type well section.

Top Contact: The Euphrates Limestone Formation from the "Early" Miocene overlies the Ibrahim Formation unconformably in the type well section.

Biostratigraphical Data: The Ibrahim Formation in the type well section contains mainly small planktonic foraminifera, but benthonic foraminifera also occur where the Azkand Limestone Formation interfingers with the Ibrahim Formation. These faunas have not been fully analysed and the Ibrahim Formation has been assigned to the Late Oligocene mainly based upon its stratigraphic position.

Al-Hashimi and Amer (1986) restudied the type well section for the Ibrahim Formation in the M.P.C. Well Ibrahim No.1, in the Mosul area of North Iraq. They recorded a planktonic foraminiferal assemblage and recognised two zones; the *Globorotalia opima* Zone and the *Globigerina angulisuturalis* Zone, which they dated as lower Mid to Late Oligocene in age.

Distribution: The Ibrahim Formation also probably occurs in wells on the Qasab and

Najmah structures. In these wells the Ibrahim Formation rests on "Mid" and "Late" Oligocene strata. Towards the northeast the Ibrahim Formation passes laterally into the Azkand Limestone Formation, and disappears to the southwest towards the centre of the sediment starved basin.

2.4.4(ii) Azkand Limestone Formation:

Type Section: Outcrop section on the north face of the Azkand cirque, 4.8 kilometres (3 miles) N-65°-E of the village of Azkand on the southern dome of the Qarah Chauq Dagh.

Author(s): van Bellen (1956).

Synonyms: with parts of the "Dolomitic Limestone" of De Boeckh *et al.* (1929), the "Kara Tchauq Dagh Series" of Nicolesco (1933) and the "Calcaire d'Asmari", the "Série d'Asmari", and possibly the "Calcaire de l'Euphrate" of Macovei (1938).

Lithological Characteristics/ Thickness: The Azkand Limestone Formation comprises a generally massive, dolomitic and recrystallised limestone, generally with high porosity and is 104 metres (340 feet) thick at the type outcrop section.

Basal Contact: The Azkand Limestone Formation unconformably overlies the Baba Limestone Formation at the type outcrop section.

Top Contact: The Anah Limestone Formation, the reef and lagoon equivalent of this unit, unconformably overlies the Azkand Limestone Formation at the type outcrop section.

Biostratigraphical Data: The Azkand Limestone Formation contains benthonic foraminifera and corals which have been used to establish two faunizones; the older *Miogypsinoides - Lepidocyclina* zone and the younger *Miogypsinoides* zone which were assigned to the Late Oligocene.

Al-Naquib (1960), studied the Azkand Limestone Formation from the Bai Hassan area of northwest Iraq. The formation is 100.5 metres (335 feet) thick and contains a similar benthonic foraminiferal assemblage as the type section with the addition of echinoids and bryozoans.

Al-Hashimi and Amer (1986), in their restudy of the Ibrahim Formation from the M.P.C. Well Ibrahim No.1, in the Mosul area of North Iraq also covered the Azkand Limestone Formation. They recorded a mixed planktonic and benthonic foraminiferal assemblage as well as algal and bryozoan remains. They assigned the Azkand Limestone Formation to the Mid Oligocene *Globorotalia opima* Zone based upon the fauna they recorded.

Distribution: The Azkand Limestone Formation is exposed in sections along the Euphrates and also occurs in M.P.C. Wells Mileh Tharthar No.1, Gussair No.1, Ibrahim No.1 and Qaiyarah No.13 and No.21.

2.4.4(iii) Anah Limestone Formation:

Type Section: Outcrop section about 15 kilometres (9 miles) east of Nahijah (Lat. 34° 26' 46'' N, Long. 41° 33' 20''E) on the Euphrates river.

Supplementary Type Section: Outcrop section 4 kilometres (2 miles) from the village of Ali Rash on a bearing of N-43° 30'-E, on the southern dome of the Qarah Chauq Dagh.

Author(s): van Bellen (1956).

Synonyms: "Dolomitic Limestone" of De Boeckh *et al.* (1929), and with parts of the following: the "Kara Tchauq Dagh Series" of Nicolesco (1933), the "Calcaire d'Asmari", the "Série d'Asmari" and the "Calcaire de l'Euphrate" of Macovei (1938), the "U. Oligocene Limestone" and the "U. Oligocene - ? Miocene Miliola Limestone" of Henson (1950).

Lithological Characteristics/ Thickness: The Anah Limestone Formation comprises a grey, brecciated, recrystallised, detrital and coralline limestone and is 45 metres (148 feet) thick at the type outcrop section. The Anah Limestone Formation in the supplementary type outcrop section is less recrystallised and dolomitized than at the type outcrop section, so that details of the lithology and fauna are better preserved. Apart from greater accessibility, this was the primary reason for setting up a supplementary type section. The Anah Limestone Formation at the supplementary type section is 60 metres (197 feet) thick, and comprises a generally white or grey dolomitized and recrystallised limestone. The formation is massively-bedded at the base and becomes more thinly-bedded upwards. The dolomitization is strongest in the upper part.

Al-Naquib (1960) described the Anah Limestone Formation from the Bai Hassan area. The Anah Limestone formation at this locality is 48 metres (160 feet) thick, and comprises a succession of cream to grey, dense, finely recrystallised back-reef and reef limestones. The limestones are locally rubbly, vuggy, with rare bluish green marl pockets and with lagoonal limestone especially towards the top. Some interfingering of completely dolomitized reef limestones occur in the upper part of the sequence.

Radosevic & Lesevic (1980) studied outcrop and well sections from the Syrian boarder to the town of Najaf. Lithologically they described the outcrops of the Anah Limestone as being sparite, biosparite, pseudoosparite and rarely micritic, with the thickness varying from 5 metres (17 feet) to 40 metres (1333 feet).

Basal Contact: The Anah Limestone Formation conformably overlies the Azkand Limestone Formation at the type outcrop section, but is not exposed at the supplementary type outcrop section.

Top Contact: The Euphrates Limestone Formation unconformably overlies the Anah Limestone Formation, and ~~this junction is marked by~~ has a conglomerate at its base at both the type outcrop section and the supplementary type outcrop section.

Biostratigraphical Data: The Anah Limestone Formation in the type outcrop section contains benthonic foraminifera, corals, algae and bryozoa which have been assigned to the Late Oligocene. The fauna in the Anah Limestone Formation at the supplementary type outcrop section is less affected by recrystallisation and dolomitization, and contains benthonic foraminifera, corals and bryozoans that were put into a faunal zone, the *Miogypsinoides* Zone which is of Late Oligocene age.

Al-Naquib (1960) in his study of the Anah Limestone Formation in the Bai Hassan area, recorded a similar fauna to that in the type and supplementary type outcrop sections which he assigned to the Late Oligocene.

Al-Qayim & Salman (1986) noted that Ctyroky & Karim (1971) in an unpublished

NIMCO Report identified *Miogypsinoides complanata* and *Austrollina howchini* from the Anah Limestone Formation, and estimated the age of the formation as either Late or lastest Late Oligocene.

Radosevic & Lesevic (1980) in their studied of outcrop and well sections from the Syrian boarder to the town of Najaf recorded benthonic foraminifera, algae, corals and molluscs which they assigned to the Late Oligocene.

Distribution: The Anah Limestone Formation is also found at Dara Khurma, Ali Rash and the Azkand cirque on the southern dome of the Qarah Chauq Dagh. A number of wells along the southern flank of the Bai Hassan structure also show it. The Anah Limestone Formation is not recognised further southwards, due to facies changes. Westward, the formation is found in M.P.C. Wells Mileh Tharthar No.1 and Anah No.1, and in a number of sections on the Euphrates River, mostly where the river runs east-west. Towards the north, outliers of the Anah Limestone Formation have been found at Shiranish where Anah Limestone Formation unconformably overlies the Pila Spi Limestone Formation.

As part of their microfacies studies for the Tertiary of Iraq, Al-Hashimi and Amer (1985) recognised 3 planktonic foraminiferal zones and 2 benthonic foraminiferal zones for the Oligocene formations mentioned above based on sub-surface and outcrop samples from a wide area of northern Iraq (see Figure 2.9).

2.4.5 Studied Well Sections:

The Kirkuk Group was sampled in the Bai Hassan No. 8, Bai Hassan No. 10, Kirkuk No. 85, Jambur No. 4, Musaiyib No. 1 and Pulkhana No. 5 well sections. These well sections are now described below but well logs containing more information on the lithologies sampled can be seen in Appendix A:

Bai Hassan No. 8: The top of the Palani Formation is sampled and is overlain probably unconformably by the Tarjil Formation which is 62.7 metres (209 feet) thick. The Tarjil Formation is overlain, probably conformably, by the Baba Limestone

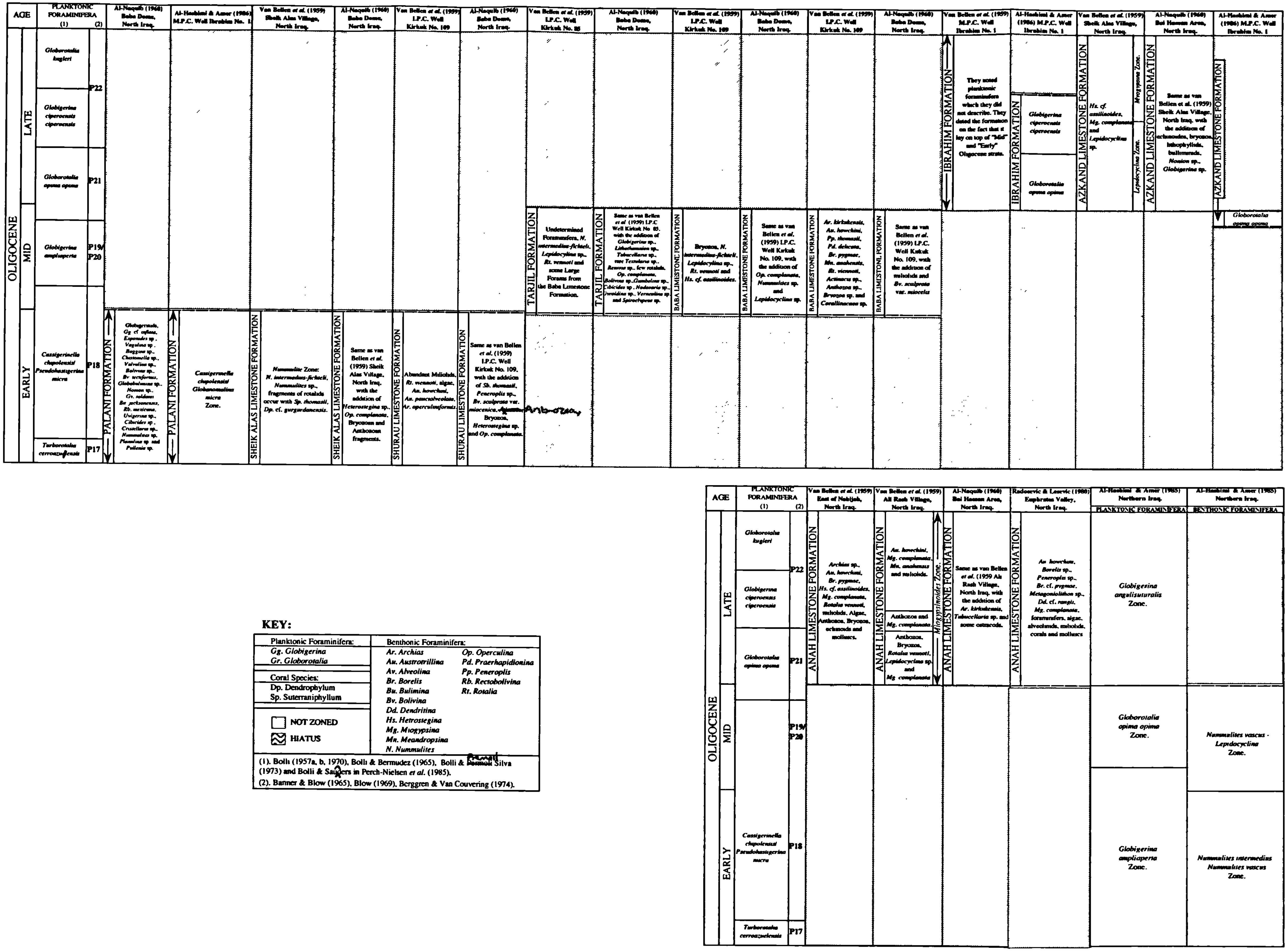


Figure 2.9 Previous Biostratigraphic Work for the Oligocene Succession of Northern Iraq.

Formation which is 44.4 metres (148 feet) thick. The Baba Limestone Formation is in turn overlain probably conformably by the Bajawan Limestone Formation which is 51.9 metres (173 feet) thick. The Bajawan Limestone Formation is then overlain by the Euphrates Limestone Formation probably unconformably.

Bai Hassan No. 10: The sampled sequence comprises the Ibrahim Formation, the Azkand Limestone Formation and the Anah Limestone Formation all of which were deposited conformably upon each other, with the Ibrahim Formation being the oldest formation and the Anah Limestone Formation being the youngest formation. The Anah Limestone Formation is 51.3 metres (171 feet) thick and the Azkand Limestone Formation is 60 metres (200 feet) thick, however only the top of the Ibrahim Formation was sampled as no more material was available in this well section. This conformable sequence with the Anah Limestone Formation at the top is overlain by the Euphrates Limestone Formation, probably unconformably.

Jambur No. 4 and Pulkhana No. 5: These well sections probably contain the Palani Formation, which was included as part of the Jaddala Formation when the well logs were drafted. The reasoning behind the belief that the Palani Formation exists in these well sections is explained under Chapter 6.0 Biostratigraphy and is illustrated in Appendix A using well logs, data sheets, range charts, and abundance diagrams.

Kirkuk No. 85: The Palani Formation is 62.4 metres (208 feet) thick and is deposited unconformably upon the Jaddala Formation, and unconformably overlain by the Tarjil Formation. Only the base of the Tarjil Formation was sampled.

Musaiyib No. 1: The Palani Formation is 127.8 metres (426 feet) thick, and is unconformably underlain by the Jaddala Formation and is overlain probably conformably by the Sheik Alas Limestone Formation. The Sheik Alas Limestone Formation is 30 metres (100 feet) thick and is overlain, probably conformably by the Shurau Limestone Formation. The Shurau Limestone is 6.6 metres (22 feet) thick and is overlain, probably unconformably by the Baba Limestone Formation. The Baba

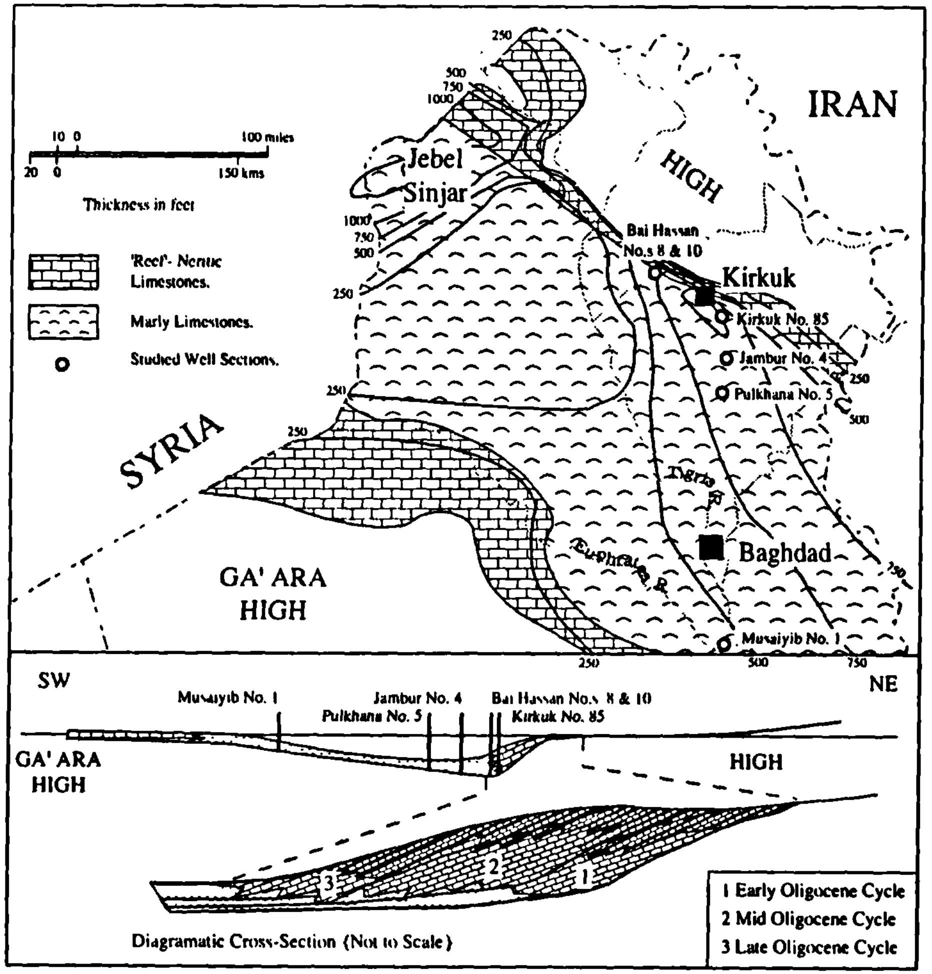
Limestone Formation is 12.9 metres (43 feet) thick and is overlain, probably conformably by the Bajawan Limestone. Only the base of the Bajawan Limestone was sampled in this well section.

2.4.6 Regional Lateral Equivalents:

Following Beydoun (1989), the Kirkuk Group can be correlated with lateral equivalents in adjacent regions. In southeastern Turkey this group of formations can be correlated with the Germik and Gaziantep Formations. In southwestern Iran correlation can be made parts of the Pabdeh, Asmari, and Jahrum Formations and the Ahwaz member. There are no equivalents to the Kirkuk Group in southern Iraq, Kuwait, Saudi Arabia, Qatar, western Abu Dhabi and Syrian and Lebanese coastal regions. However, in central and eastern Abu Dhabi and the United Arab Emirates the Pabdeh, Clastics and the Asmari Formations correlate with the Kirkuk Group. The Kirkuk Group is also equivalent to parts of the Dahek, Anah, Abiad and the Bichri Formations in the interior of Syria. In Jordan, the Kirkuk Group equivalents are the Taiyiba Formation and part of the Usdom Formation and in Israel the Beit Guvrim Formation.

2.4.7 Sedimentology and Depositional History:

The sedimentology and depositional history for this time interval is based upon van Bellen *et al.* (1959), Dunnington (1958), Buday (1980), Al-Hashimi and Amer (1986) and Beydoun (1989), and is illustrated in Figure 2.10. At the end of the Late Eocene the Pyrenean orogeny caused the uplift of the area which resulted in widespread erosion in Iraq. This led to the Oligocene succession being unconformably deposited on the Mid to Late Eocene succession. Sedimentation during the Oligocene was restricted to a relatively narrow basin which ran northwest-southeast across the area, from the Mediterranean Sea, to north of the Ga'ara High and into the Arabian Gulf. Therefore, the Oligocene succession is not represented in southern Iraq. The Kirkuk Group was deposited as a series organic reefs in three cycles each comprising a back-reef, fore-reef and offshore facies. The Early Oligocene cycle comprises the Shurau Limestone, Sheik Alas Limestone and Palani Formations. The Mid Oligocene cycle



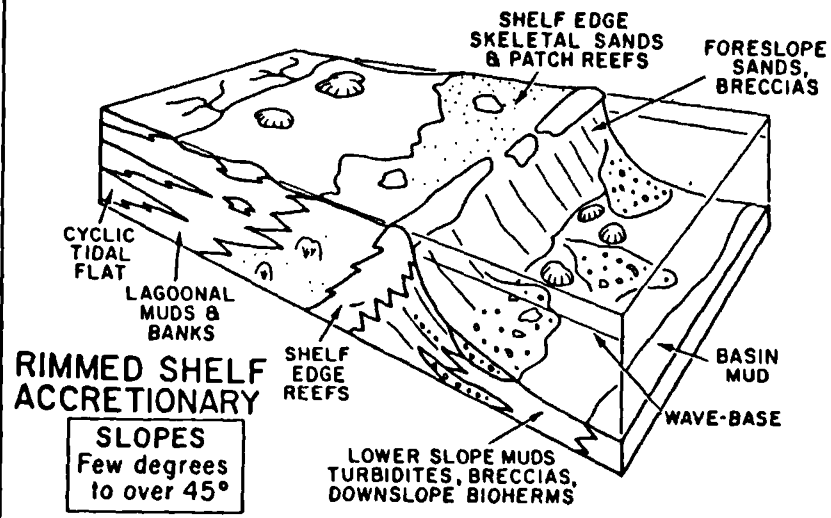


Figure 2.10. Isopach-Facies Map & Model for the Oligocene of Northern Iraq (Partly modified after Dunnington, 1958 & Read, 1985 respectively).

comprises the Bajawan Limestone, Baba Limestone and Tarjil Formations. The Late Oligocene cycle comprises the Anah Limestone, Azkand Limestone and the Ibrahim Formations. The base and top of the three cycles is marked by a transgressive and regressive phase respectively. These transgressions established unconformities between each cycle. These three Oligocene cycles were deposited on both sides of the narrow basin but, the succession is thicker on the northern basin margin as it is steeper than the southern basin margin. The globigerinid, marly limestones of the offshore facies thinned towards the centre of the basin from both sides. The simple geometry of this basin running northwest-southeast separating two topographic highs, one to the northeast and one to the southwest (Ga'ara High), is complicated by the presence of a series of internal troughs. These troughs occur in the same locations as the Mid to Late Eocene internal troughs, except that the trough that occurred northwest of Kirkuk was no longer active during the Oligocene. The Ga'ara High in the southwest of the area increased its influence again during the Oligocene, and so helped to restrict the Oligocene succession to the north of Iraq by preventing sediment passing towards the south.

Majid and Veizer (1986) suggest a similar model for work they carried out on the Early and Mid Oligocene cycles, based upon the work of Read (1985). This sediment deposition model is illustrated in Figure 2.10 along with a map of the distribution of formations in the Oligocene time interval. Majid and Veizer (1986) preferred the term bioherm to reef to describe the Shurau and Bajawan limestones as the limestones lack frame-building organisms in their growth positions, however they did not rule out the possibility of some isolated patch reefs. Majid and Veizer (1986) explained the lack of true reefs within the Kirkuk Group by following the work of Walker and Alderstadt (1975), and suggested that the "reef" development was arrested during its pioneer stage. This arrested development led to the series of shoal accumulations of skeletal (forams, echinoderms, corals and red algae) lime sands, many in a muddy matrix. Majid and Veizer (1986) also referred to these "reefs" as "half-reefs" or "incomplete reefs" in the sense of James (1984). In their studies Majid and Veizer also considered the geochemical nature of the nearshore and offshore basinal sediments, and found that the nearshore sediments had low sodium and strontium contents as well as light $\delta^{18}O$ and $\delta^{13}C$. In contrast the basinal sediments have the opposite attributes and foreshore deposits had intermediate sodium, strontium and oxygen and carbon contents. Majid and Veizer (1986) explained these results by the fact that nearshore sediments in the nearshore area were deposited in water with a marked meteoric aspect while the basinal sediments were laid down in water with a similar composition of present day seawater. The foreslope sediments were deposited in waters with intermediate compositions between meteoric water and seawater. This relatively simple model for this group of formations is complicated, as interfingering and intergrading occurs between these formations reflecting them effectiveness of the "reef"-type (bioherm) limestones as a barrier.

2.5 Early Miocene:

Van Bellen *et al.* (1959) placed the Serikagni, Euphrates Limestone, Dhiban Anhydrite and the Jeribe Limestone Formations into this time-interval. However, they pointed out that the assigned age for this group of formations has no direct correlation with the European standard Early Miocene. In fact some doubts about the age of the Jeribe Limestone Formation are discussed later. A map showing the location of outcrop and well sections used in previous studies to describe the formations in this time-interval can be seen in Figure 2.11. In addition, a summary diagram of the biostratigraphic data from all these previous works can be seen in Figure 2.12.

2.5.1 Serikagni Formation:

Type Section: Outcrop section near the village of Bara (Lat. 36° 20' 30'' N, Long. 41° 29' 00'' E) in the Jebel Sinjar area of the Foothill Zone of northwest Iraq.
Author(s): van Bellen (1955).
Synonym: "Marnes crayeuses jaunâtres" of Dubertret (1935).
Lithological Characteristics/ Thickness: The Serikagni Formation comprises a globigerinid, chalky limestone with a few more calcareous bands. However, the lithology is very variable and ranges from purely globigerinid marls to algal/ reef limestones with all intermediate gradations. Overall, the Serikagni Formation is 145

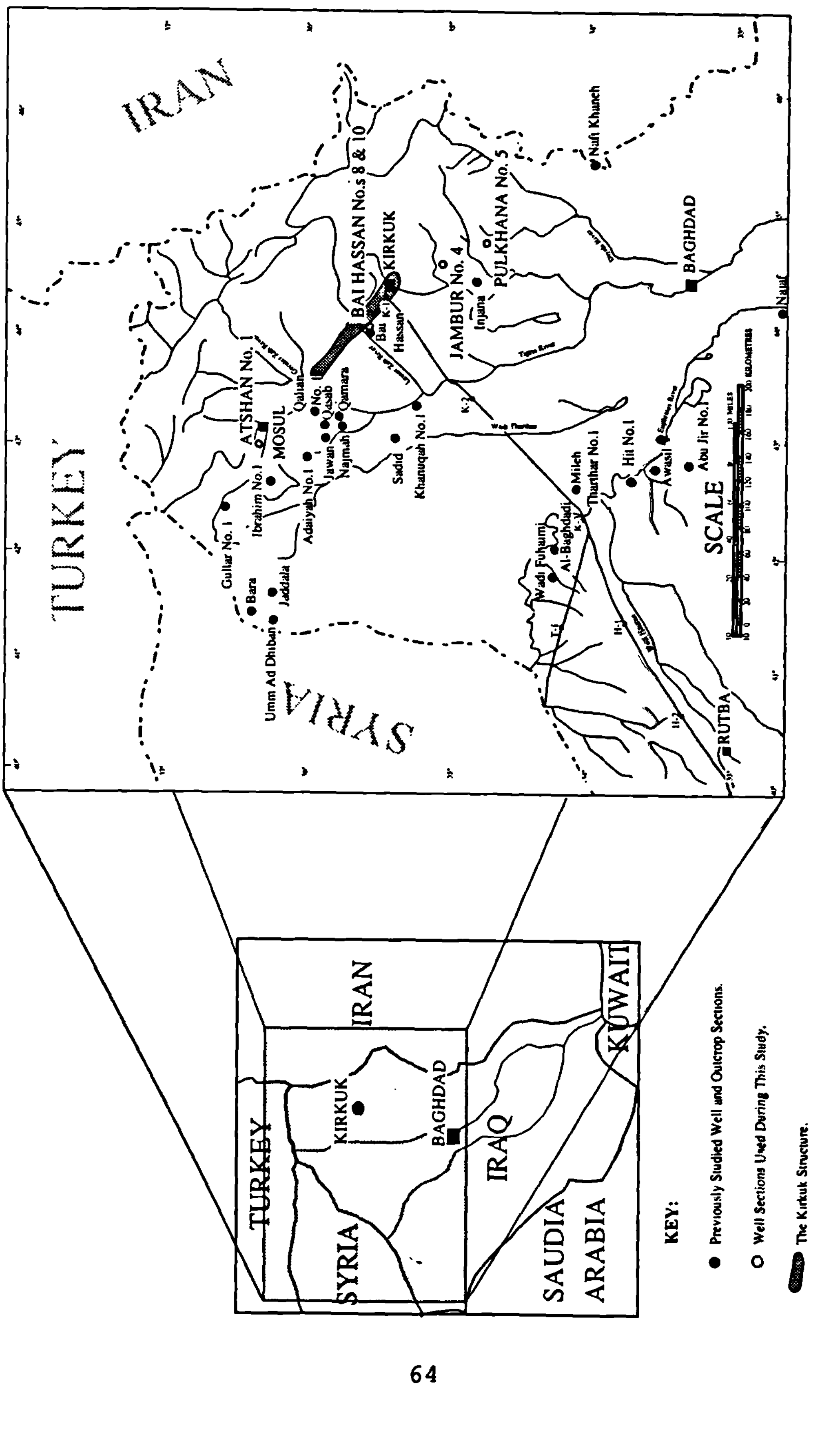


Figure 2.11 Location Map of Previously Studied Outcrop and Well sections, and the Well Sections used during this Present Study for the Early Miocene Time Interval.

metres plus a possible 6 metres (475 feet, + 20 feet ?) at the type outcrop section.

Basal Contact: The Serikagni Formation unconformably rests upon the Jaddala Formation at the type locality. The unconformity is demonstrated by the absence of Oligocene sediments, which may be due to scouring of the sea-bottom on which the Oligocene sediments were deposited. Elsewhere, the Ibrahim Formation is found to underlie the Serikagni formation slightly further towards the east. The Azkand Limestone Formation underlies the Serikagni Formation in M.P.C. Well Adaiyah No.1, and in the Qasab area a thin anhydrite, perhaps correlatable with the Basal Anhydrite, underlies the Serikagni Formation. The base of the Serikagni Formation is frequently sub-conglomeratic, marking an erosional unconformity. The characteristic lithofacies of the sub-conglomeratic beds is a globigerinid limestone, in which the chambers of the globigerinids are filled with extraneous carbonaceous material, and which contain pyritized pellets and blackened sub-ooliths. Sections showing this sub-conglomeratic basal development include M.P.C. Well Ibrahim No.1 and I.P.C. Well Injana No.1.

Top Contact: The Serikagni Formation is overlain conformably and generally gradationally by the Dhiban Anhydrite Formation at the type locality and section. Elsewhere, the Euphrates Limestone Formation conformably overlies the Serikagni Formation. This situation exists in the Qaiyarah, Jawan and Qasab wells, and in the M.P.C. wells Qalian No.1, Adaiyah No.1, Ibrahim No.1 and Gussair No.1.

Biostratigraphical Data: The Serikagni Formation contains Early Miocene echinoids, lamellibranchs and abundant planktonic foraminifera.

Al-Naquib (1960), described the Serikagni Formation from the Jambur, Pulkhana and the Injana areas of northern Iraq.

1. Jambur Area: The Serikagni Formation is a variable marly limestone, dolomitic in part, with some shelly and algal bands; it may also be silty and pyritic. The fauna is essentially globigerinid, but benthonic foraminifera, crustacea and lamellibranchs also frequently occur. The Serikagni Formation unconformably overlies the Jaddala Formation and is conformably overlain by the Dhiban Anhydrite formation or the Euphrates Limestone Formation in this area and has been dated as Early Miocene in age.

2. Pulkhana Area: The Serikagni Formation is about 23.1 metres (77 feet) thick and comprises a bluish-grey or brown marly, globigerinid rich, limestone, that also contains some benthonic foraminifera. The top of the Serikagni Formation here is marked by a limestone band rich in coralline algae and other shelly material; the formation has been assigned an Early Miocene age.

3. Injana Area: The succession is 60 metres (200 feet) thick and shows a very similar lithology as the type area. The formation contains both planktonic and benthonic foraminifera, algae, bryozoa, gastropods and lamellibranchs. The Serikagni Formation interfingers with the Euphrates Limestone Formation but is overlain conformably by the Dhiban Anhydrite Formation and is unconformably underlain by the Jaddala Formation in this area. The Serikagni Formation has again been assigned to the Early Miocene in this area.

Al-Hashimi and Amer (1986) in their re-investigation of the Ibrahim Formation from the M.P.C. Well Ibrahim No.1 from the Mosul area of North Iraq identified planktonic foraminifera from the Serikagni Formation which they assigned to the lower Early Miocene and the *Globigerinoides primordius/ Globorotalia kugleri* Zone.

2.5.2 Euphrates Limestone Formation:

Type Section: Outcrop section near Wadi Fuhaimi (Lat. 34° 15' 58" N, Long. 42° 08' 09" E).

Author(s): Described in part by de Boeckh *et al.* (1929), later emended by van Bellen (1957).

Synonyms: "Asmari" and the "Euphrates Limestone" of Noble (1926); the "Kara Tchauq Dagh" and the "Strate de Kara Tchauq Dagh", and part of the "Asmari", the "Série de l'Euphrate" and the "Calcaire de l'Euphrate" of Nicolesco (1933), part of the "Série d'Asmari" and the "Calcaire de l'Euphrate" of Macovei (1938) and finally, part of the "Série de l'Euphrate" of Mitchell (1956).

Lithological Characteristics/ Thickness: The Euphrates Limestone Formation comprises a shelly, chalky, well-bedded recrystallised limestone and is 8 metres (26 feet) thick at the type outcrop section.

Basal Contact: The Euphrates Limestone Formation overlies the Anah Limestone Formation at the type outcrop section and the contact appears to be erosional due to the presence of a conglomerate at the ~~junction between the two~~ base of the Euphrates Limestone formation~~s~~. This situation also occurs at Wadi Haglan but here the conglomerate varies in thickness between the two formations.

A thin anhydrite occurs between the Euphrates Limestone and the underlying Oligocene in the M.P.C. wells Ibrahim No.1, Qasab No.2, No.3 and No.5a, wells on the Najmah structures, Sadid No.1 and Khanuqah No.1, in I.P.C. wells on the Jambur structure and wells near Naft Khaneh and Chia Surkh. It is possible that the anhydrite is equivalent to the Kalhur Gypsum (anhydrite) as known from the Naft Khaneh area and regions in Iran.

Top Contact: The Jeribe Limestone Formation overlies the Euphrates Limestone Formation, the contact being conglomeratic. Despite the unconformable relationship of the two formations, the Jeribe Limestone and the Euphrates Limestone are lithologically very similar, the only differences being:

1. The predominance of chilostomellids over miliolids in the Jeribe Limestone and the reverse situation in the Euphrates Limestone.

2. The presence of *Borelis melo* (Fichtel & Moll) var. *curdica* Reichel in the Jeribe Limestone, and the absence of this fossil in the Euphrates Limestone.

3. The dominance of recrystallised limestone in the Jeribe Limestone Formation and the dominance of dolomitized limestones in the Euphrates limestones, although both types in both formations. Oolitic and suboolitic limestones are virtually confined to the Euphrates Limestone although they do occur to a limited extent in the Jeribe Limestone Formation.

Biostratigraphical Data: The Euphrates Limestone Formation contains benthonic foraminifera, gastropods, lamellibranchs and rare bryozoa, most of which are badly preserved and indeterminate. The Euphrates Limestone Formation is considered to be "Early" Miocene in age, on the basis that it interfingers with the Serikagni Formation (which has been dated using palaeontological evidence), and that the formation lies above the well-defined Miocene/ Oligocene unconformity.

2.0 General Geology

Al-Naquib (1960), described the Euphrates Limestone Formation in four areas: the Jambur area, the Pulkhana area, the Injana area and the Bai Hassan area. In the Jambur area the Euphrates Limestone comprises a sequence of strongly recrystallised, flocculitic, and dolomitic lagoonal limestones with occasional chert nodules and secondary interstitial anhydrite. The Euphrates Limestone, in this area, interfingers and grades up into the Dhiban Anhydrite Formation and interfingers and grades down into the Serikagni Formation. The fauna, which is usually obliterated by recrystallisation includes gastropods, miliolids, chilostomellids, peneroplids, rotalids and crustacean debris. Elsewhere *Dendritina* sp. and *Rotalia beccarii* Linn. have been described. Over the Jambur area the Euphrates Limestone Formation varies from a few feet (ten's of centimetres) to 84 metres (280 feet). In the Pulkhana crestal area one deep well has penetrated 4.8 metres (16 feet) of dolomitic limestone belonging to the Euphrates Limestone Formation. On the Injana structure, the Euphrates Limestone is hardly represented as an independent unit, but occurs as thin bands, interfingering with the dominant Serikagni Formation. The thickness variation in the Euphrates Limestone Formation in the above areas is probably related to local highs which started forming during the "Early" Miocene. In the Bai Hassan area the Euphrates Limestone Formation lies unconformably on the Anah Limestone Formation and not on Eocene beds as observed in the southern parts of this region.

Radosevic & Lesevic (1980) in their studied of outcrop and well sections near the Syrian boarder close to the town of Najaf recorded benthonic foraminifera from the Euphrates Limestone Formation which they assigned to the Early/ Mid Miocene.

Abawi (1989) studied both benthonic and planktonic foraminifera from the Euphrates Limestone in a outcrop section at Sharafaddin in northwest Iraq and assigned a late Early Miocene age to the formation.

Ashoor and Sayyab (1989) studied benthonic foraminifera from three outcrop sections in the Euphrates Limestone Formation at Khan Al-Baghdadi area, west of Baghdad, in northern Iraq, and assigned an Early Miocene age to the formation.

Distribution: The Euphrates Limestone Formation is present in numerous oil-wells and in outcrop in northern Iraq. The formation can also be recognised in exposures in southern Iraq but here the facies is slightly different and contains more sand. The Euphrates Limestone has not as yet been recognised in wells in southern Iraq and the relationship between the Euphrates Limestone and the limestones in the Lower Fars, Ghar and the Zahra Formations is unclear.

2.5.3 Dhiban Anhydrite Formation:

Type Section: Outcrop section near Umm ad Dhiban, 4590 feet (1400 metres) east of a ruined caracol (Lat. 36° 16' 25'' N, Long. 41° 21' 32'' E).

Author(s): Henson (1950), emended by van Bellen (1957).

Lithological Characteristics/ Thickness: The Dhiban Anhydrite Formation at the type locality comprises: 42.5 metres (139 feet) of gypsum, overlying 0.5 metres (1.6 feet) of brecciated, recrystallised limestone. This in turn rests on 26 metres (85 feet) of gypsum and thin bands of creamy marl, which overlies a basal unit of 3 metres (10 feet) of gypsum. In total the Dhiban Anhydrite is 72 metres (235.6 feet) thick.

Basal Contact: The underlying formation at the type locality is unknown but in the immediate vicinity the Dhiban Anhydrite Formation is underlain by the Serikagni Formation. This contact is somewhat sharper (though not unconformable) than the interfingering gradational contact between the Dhiban Anhydrite Formation and the Euphrates Limestone Formation evident in other areas.

Top Contact: The Jeribe Limestone Formation appears to unconformably overlie the Dhiban Anhydrite Formation at the type outcrop section.

Biostratigraphical Data: An "Early" Miocene age was given to the Dhiban Anhydrite Formation based mainly on its stratigraphic position.

Al-Naquib (1960), described the Dhiban Anhydrite Formation from the Jambur area, the Pulkhana area and the Injana area.

In the Jambur area the Dhiban Anhydrite Formation shows a marked variation in thickness ranging from 27-45 metres (90-150 feet). The succession is generally very similar to that recorded at the type locality and section but contains occasional thin blue marls and not the creamy white marls seen at the type locality. The limestone at this locality also contain chilostomellids, rotalids, *Miogypsina* sp., molluscs and crustacean debris.

In the Pulkhana area the Dhiban Anhydrite Formation is about 126 metres (420 feet) thick and is represented by a series of thick bands of anhydrite, interbedded with dolomite and dolomitic limestones. The limestone are lagoonal facies and contain lamellibranchs, gastropods, echinoids debris, rotalids and miliolids.

In both the Jambur and Pulkhana areas the Dhiban Anhydrite Formation is transgressively overlain by the Jeribe Limestone Formation and passes laterally and downwards into the Euphrates Limestone Formation.

In the Injana area the Dhiban Anhydrite Formation is about 141 metres (470 feet) thick and is very similar to the sequence described above. Here however, the Dhiban Anhydrite Formation lies directly on the Serikagni Formation and is overlain by the Jeribe Limestone Formation.

Distribution: The Dhiban Anhydrite Formation is probably also represented by evaporites in other areas, as in the M.P.C. wells on the Qaiyarah, Jawan, Najmah and Qasab structures. In some areas the Dhiban Anhydrite is missing altogether as in M.P.C. wells Abu Jir No.1, Awasil No.1, Gusair No.1, Hit No.1 and Mileh Tharthar No.1. In such cases the base of the overlying formation (the Jeribe Limestone Formation) is slightly sub-conglomeratic, marking an unconformity between the two formations. The top of the underlying formation, the Euphrates Limestone Formation, is also conglomeratic. It is possible that the Dhiban Anhydrite formation can be correlated directly with the Kalhur Gypsum as both occur below limestones containing *Borelis melo* (Fichtel & Moll) var. *curdical* Reichel (van Bellen *et al.*, 1959).

2.5.4 Jeribe Limestone Formation:

Type Section: Outcrop section near Jaddala Village, Jebel Sinjar (Lat. 36° 18' 00''N, Long. 41° 41' 00''E).

Author(s): First mentioned by Damesin (1936), and was defined first by van Bellen (1957)

2.0 General Geology

Synonyms: Part of the "Euphrates Limestone", Noble (1926); "Euphrates Limestone", De Boeckh *et al.* (1929); "Asmari" De Boeckh *et al.* (1929); "Série de l'Euphrate", Nicolesco (1933); "Calcaire de l'Asmari", Nicolesco (1933); "Asmari" Nicolesco (1933); "Série d'Asmari" Macovei (1938); "Calcaire d'Asmari" Macovei (1938) and the "Calcaire de l'Euphrate" Macovei (1938).

Lithological Characteristics/ Thickness: The Jeribe Limestone Formation comprises a recrystallised and dolomitic, massively bedded limestone, with individual beds 1.8 metres (6 feet) in thickness. In total the Jeribe Limestone Formation is 73 metres (240 feet) thick at the type outcrop section but, the top of the formation is obscured by 15 metres (50 feet) of gravel drift, which replaces the space once occupied by an anhydrite unit which occurs at the base of the Lower Fars Formation.

Al-Naquib (1960), recorded a similar lithology as recorded in the Pulkhana, Jambur and Injana areas as in type outcrop section. He also suggested that the Jeribe Limestone Formation rests conformably on the Dhiban Anhydrite Formation and is transgressively overlain by the Lower Fars Formation. Al-Naquib also noted that in some other areas the Jeribe Limestone may lie unconformably on Oligocene strata.

Basal Contact: The Jeribe Limestone Formation rests unconformably on the Serikagni Formation at the type outcrop section as no Dhiban Anhydrite occurs.

Top Contact: The Jeribe Limestone Formation is unconformably overlain by the Lower Fars Formation.

Biostratigraphical Data: The Jeribe Limestone Formation at the type outcrop section has been assigned a Miocene age probably "Early" based on the benthonic foraminifera it contains. The fauna within the Jeribe Limestone Formation was also used to separate the formation into three facies; a lagoonal facies, a lithophyllid reef and a detrital facies probably deposited infront of the lithophyllid facies in a gulf or extended sea arm.

Al-Naquib (1960) recorded a similar fauna from the Pulkhana, Jambur and Injana areas in Iraq which he assigned to the Early Miocene.

Buday (1980) assigned the Jeribe Limestone Formation to the Mid Miocene and linked the formation to the basal Lower Fars. He assigned this age based partly upon the work of Ditmar *et al.* (1971) who noted that the Jeribe Limestone Formation was equivalent to the limestone-dominated parts of the Lower Fars Formation and had *Orbulina* near its base. The faunal change between the Euphrates Limestone and the Jeribe Limestone and the appearance of transgressive, basal conglomerates within the Jeribe Limestone led to the Mid Miocene age being assigned to the Jeribe Limestone Formation.

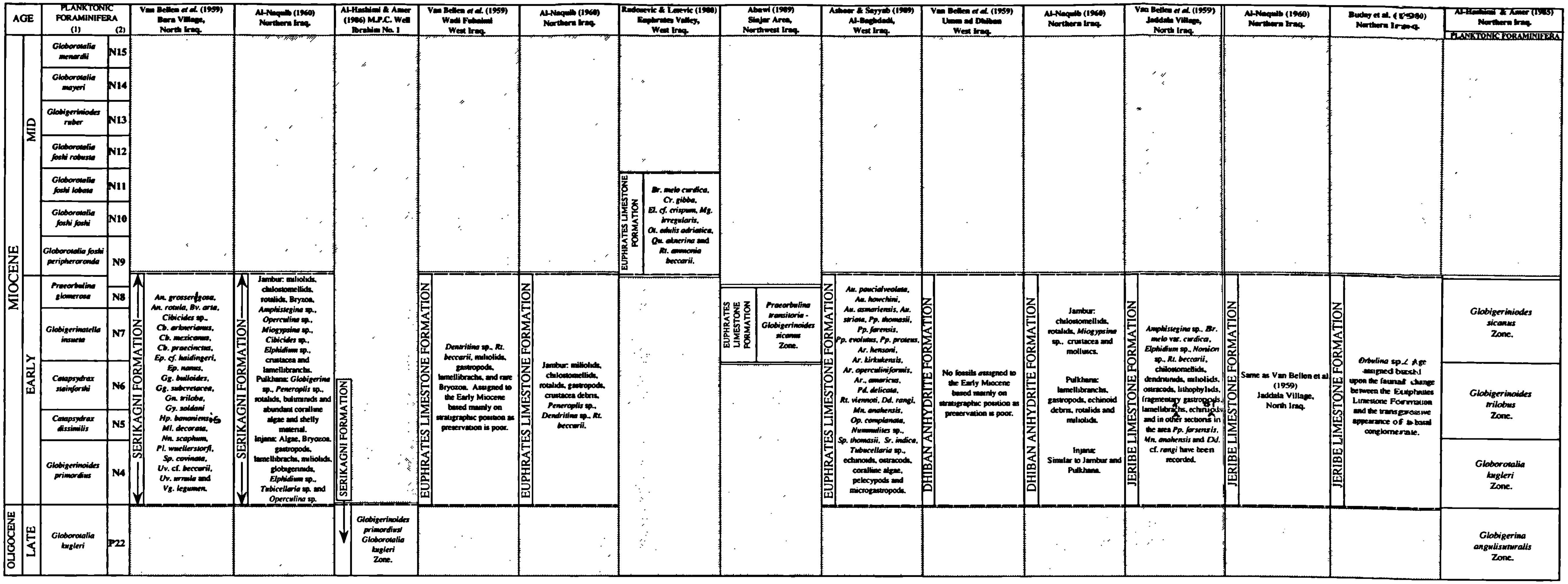
Distribution: The Jeribe Limestone Formation occurs over a wide area at the surface and in well sections in northern Iraq. To the northeast of the type section it is found in Ain Zahlah-Mushorah area. To the southeast it occurs on both sides of the River Tigris between Mosul and the confluence of the River Lesser Zab. In the western part of Iraq, the formation crops out around Nahiyah and has subsurface occurrences in the M.P.C. Well Mileh Tharthar No. 1, and M.P.C. wells in the Awasil area. Observations in the Jawan-Najmah-Qaiyarah-Qasab group of structures show that the Jeribe Limestone thickness is dependent on its position in the structure. Crestal wells show thinner Jeribe Limestone than the deeper down-flank wells, this is a strong indication that structures were rising during the deposition of the formation. The Jeribe Limestone is not recognised in southern Iraq.

As part of their microfacies studies for the Tertiary of Iraq, Al-Hashimi and Amer (1985) recognised 3 planktonic foraminiferal zones for the Early Miocene formations mentioned above based on sub-surface and outcrop samples from a wide area of northern Iraq (see Figure 2.12).

2.5.5 Studied Well Sections:

This group of formations is encountered in Atshan No. 1, Bai Hassan No. 8, Bai Hassan No. 10, Jambur No. 4, Pulkhana No. 5:

Atshan No. 1 The base of the Euphrates Limestone Formation is sampled and rests on the Avanah Limestone/ Jaddala Formations probably unconformably.



KEY:

Planktonic Foraminifera:	Benthonic Foraminifera:	
Gg. Globigerina	*An. Anomalina*	*Mg. Miogypsina*
Gn. Globigerinoides	*Ar. Archias*	*Mi. Marginula*
Gr. Globorotalia	*Au. Austrotrillina*	*Mn. Meandropsina*
	Av. Alveolina	*Nn. Nonion*
Coral Species:	*Br. Borelis*	*Op. Operculina*
Dp. Dendrophylum	*Bu. Bulimina*	*Ot. Ostrea*
Sp. Suterraniphyllum	*Bv. Bolivina*	*Pl. Planulina*
	Cb. Cibicides	*Pd. Praerhapidionina*
	Dd. Dendritina	*Qu. Quinqueloculina*
	El. Elphidium	*Pp. Peneroplis*
NOT ZONED	*Ep. Eponides*	*Rb. Rectobolivina*
HIATUS	*Gy. Gyroidina*	*Rt. Rotalia*
	Hp. Hopkinsina	*Uv. Uvigerina*
	Hs. Hetrostegina	*Vg. Vagulina*

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & ~~Permoli~~ Premoli Silya (1973) and Bolli & Saunders in Perch-Nielsen *et al.* (1985).
(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvering (1974).

Figure 2.12 Previous Biostratigraphic Work for the Late Oligocene to Mid Miocene Succession of Northern Iraq.

Bai Hassan No. 8 The Euphrates Limestone Formation is 15 metres (49 feet) thick and rests probably unconformably upon the Bajawan Limestone Formation. The Euphrates Limestone is overlain again probably unconformably by the Lower Fars Formation (Transition Beds).

Bai Hassana No. 10 The Euphrates Limestone Formation is 14 metres (47 feet) thick and rests probably unconformably upon the Anah Limestone Formation. The Euphrates Limestone Formation is overlain by the Lower Fars Formation (Transition Beds) again probably unconformably.

Jambur No. 4 The Serikagni Formation is 57 metres (190 feet) thick in this well section and as has previously been stated to rest unconformably upon the Jaddala Formation but, as explained earlier this is incorrect and the Serikagni Formation was actually rests unconformably upon the Palani Formation. The full explanation for this formation being selected is shown in Chapter 6.0 Biostratigraphy. The Serikagni Formation is overlain probably conformably by the Dhiban Anhydrite Formation, which is 153.3 metres (511 feet) thick. The Jeribe Limestone Formation overlies the Dhiban Anhydrite Formation again probably conformably, and is 41.7 metres (139 feet) thick. The Jeribe Limestone Formation is overlain probably unconformably by the Lower Fars Formation (Transition Beds).

2.5.6 Regional Lateral Equivalents:

Following Beydoun (1989), the Serikagni, Euphrates Limestone, Dhiban Anhydrite and the Jeribe Limestone Formations can be correlated with lateral equivalents in adjacent regions. In southeastern Turkey this group of formations can be correlated with the Silvan, Firat and Lice Formations. In southwestern Iran correlation can be made with parts of the Kalhur, Ahwaz, Guri members and the Asmari, Gachsaran and Razak Formations. There are only a few equivalents to this group of formations in southern Iraq, Kuwait, Saudi Arabia, Qatar and western Abu Dhabi: the Abu Ghar, Hadrukh and Dam Formations. In central and eastern Abu Dhabi and the United Arab Emirates this group of formations correlates with the Pabdeh, Clastics and the Asmari

Formations. This group of formations is also equivalent to the Serikagni, Euphrates Limestone, Dhiban Anhydrite, Jeribe Limestone, Bichri, Anah Limestone, Manqoura, Janoudiye and Qourt Qoulaq Formations in Syria. In Jordan this group of formations is equivalent to part of the Usdom Formation. This group of formations also has unnamed equivalents in Lebanon, and is equivalent to lower part of the Ziqim Formation, part of the Sakieh Beds, in Israel.

2.5.7 Sedimentology and Depositional History:

The sedimentology and depositional history for this time interval is based upon van Bellen *et al.* (1959), Dunnington (1958), Buday (1980) and Al-Hashimi and Amer (1985) and Beydoun (1989), and is illustrated in Figure 2.13. The third and final Oligocene cycle was terminated by a regression caused by the Savian Orogeny which affected sedimentation through the Early Miocene. Sedimentation in the Early Miocene again occurred in the broad linear, northwest-southeast basin but, now the basin was shallower than previously and has two internal troughs. The first trough occurred south of Jebel Sinjar and the second occurs to the extreme northeast of Jebel Sinjar both represent reactivated Mid to Late Eocene troughs. The Euphrates Limestone Formation was deposited on the margins of the basin while in the centre more open marine conditions favoured deposition of the globigerinid, marly limestones of the Serikagni Formation. These two formations frequently interfinger suggesting that conditions in the basin fluctuated during their deposition. After the deposition of these two formations the area again suffered from orogenic movements which partially or temporarily closed this marine channel, allowing the deposition of the evaporitic sequence of the Dhiban Anhydrite Formation. The basin then partially re-opened which allowed the deposition of the lagoonal limestones of the Jeribe Limestone Formation. At the end of the Early Miocene the basin opened further, allowing the transgressive deposition of the Lower Fars Formation of Mid Miocene age.

SOUTHERN IRAQ

2.6 Palaeocene to Early Eocene and Mid to Late Eocene:

In southern Iraq the Palaeocene to Early Eocene and the Mid to Late Eocene are

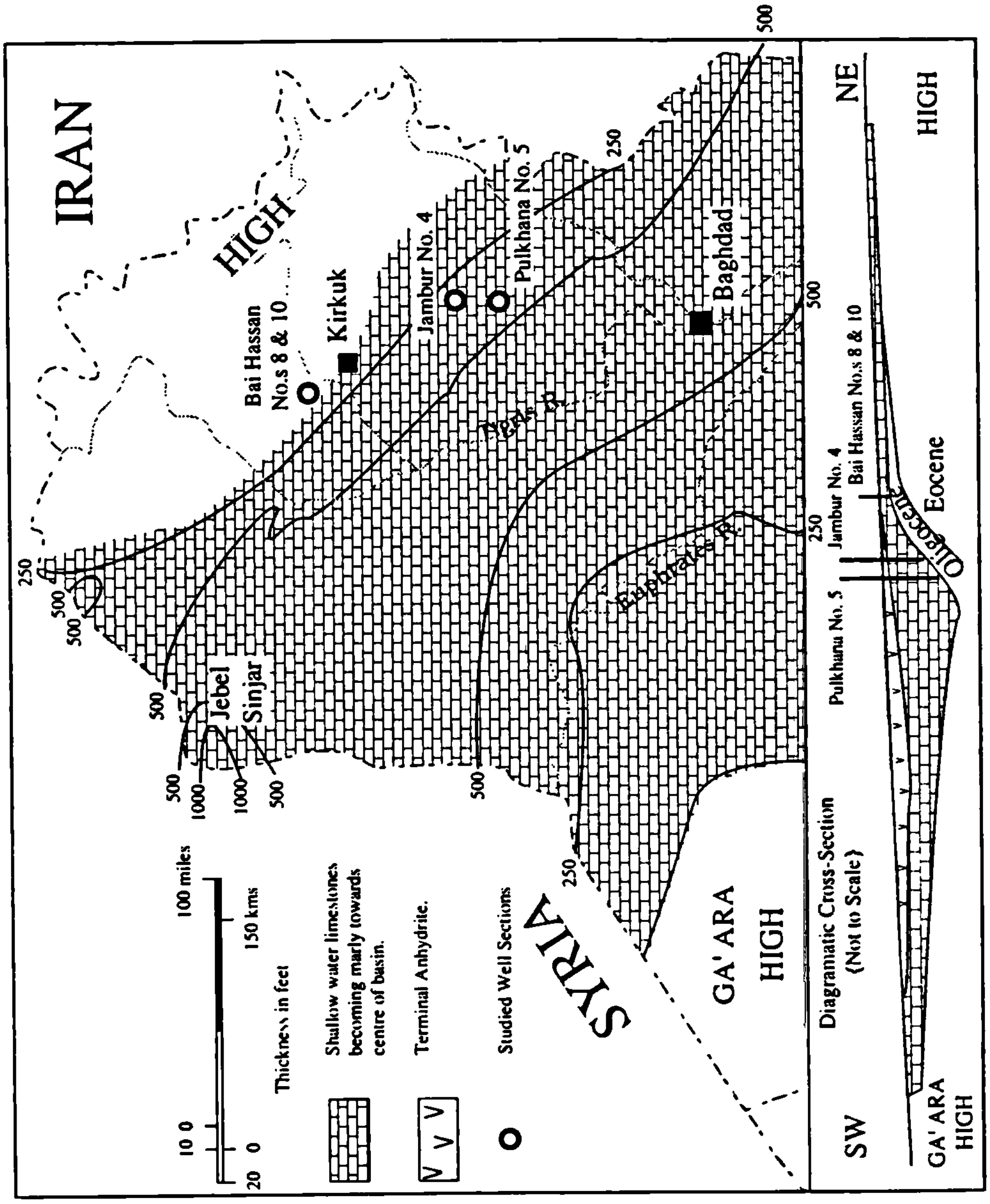


Figure 2.13. Isopach-Facies Map for Early-Middle Miocene (Partly modified after Dunnington, 1958).

represented within the Hasa Group which is described in detail below. The ages assigned to the formations in this group again have no direct correlation with the European standard Palaeocene and Early, Mid and Late Eocene stages.

THE HASA GROUP

The Hasa Group is a widespread, readily recognizable and useful unit in southern Iraq. The term was originally introduced by Sander (1952) based on work he carried out in Saudi Arabia and adopted for Iraq by Owen and Nasr (1958). The work of Owen and Nasr (1958) Steineke, Bramkamp & Sander, 1958 and van Bellen *et al.* (1959) forms the main source of information on Hasa Group for this study.

The Hasa Group consists of three formations:

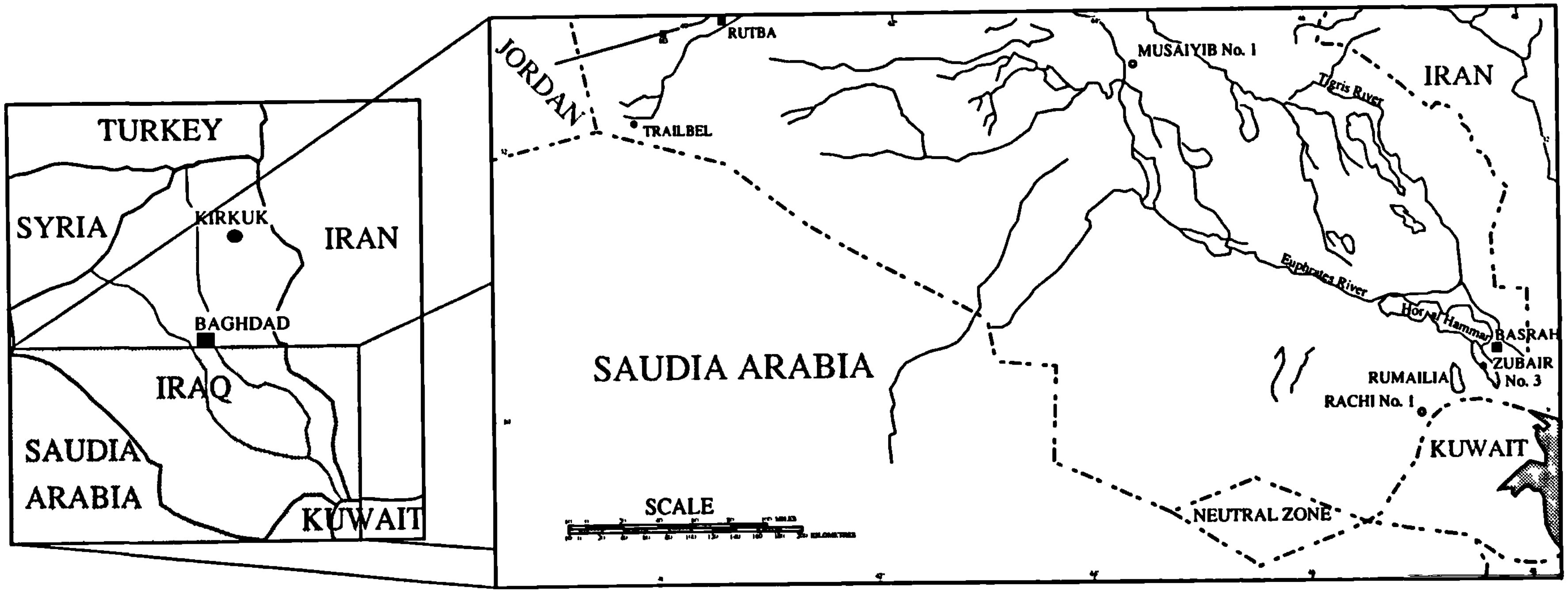
1. Umm Er Radhuma Formation (Palaeocene to "Early" Eocene).
2. Rus Formation ("Early" Eocene).
3. Dammam Limestone Formation (late "Early", Mid, early "Late" Eocene).

The Hasa Group is synonymous with the "Bahrein Series" of Pilgrim (1908). This correlation was rejected by Sander (1952) because the Hasa area of Saudi Arabia shows a better succession of formations than described by Pilgrim (1908) from the Bahrein peninsula. A map showing the location of outcrop and well sections used in previous studies to describe the formations in this time-interval can be seen in Figure 2.14. In addition, a summary diagram of the biostratigraphic data from all these previous works can be seen in Figure 2.15.

2.6.1 Umm Er Radhuma Formation:

Type Section: Well sections close to water wells situated near Umm er Radhuma, in Eastern Saudi Arabia (Lat. 28° 41' N, Long. 44° 41' E). However, difficulties in working out the full sequence in these well sections lead to a standard outcrop section being set up for this unit in the Wadi al Batin between the points of 149.8 kilometers (93.1 miles) and 70.4 kilometers (43.8 miles) southwest of Hafar al Batin (between Lat. 27° 32' N, Long. 44° 52' E and Lat. 27° 59' N, Long. 45° 29' E).

Supplementary Type Section: B.P.C. Well Zubair No.3 (Lat. 30° 23' 01'' N, Long.



KEY:

● Previously Studied Well and Outcrop Sections.

○ Well Sections Used During This Study.

Figure 2.14 Location Map of Previously Studied Outcrop and Well sections, and the Well Sections used during this Present Study for the Palaeocene to Late Eocene Time Interval in Southern Iraq.

47° 43' 29'' E), between the drilled depths of 909 metres (2980 feet) and 1367 metres (4482 feet).

Synonyms: "Radhuma Formation" of Fox (1956,1957), the "Formation d'Auja" of Michell (1956) and the "Radhuma Formation" of Owen & Nasr (1959).

Lithological Characteristics/ Thickness: The Umm er Radhuma Formation comprises:

(3). Grey and cream coloured limestone, dolomitic limestone and dolomite with moulds of fossil fragments and poorly preserved foraminifera; silicified layers occur at several horizons (140 metres, 459 feet thick).

(2). Light coloured, relatively soft, partly chalky limestone (74 metres, 243 feet thick).

(1). Light tan to grey, hard, dolomitic limestone and dolomite (15 metres, 49 feet thick).

Overall, the Umm Er Radhuma Formation is 229 metres (751 feet) thick at the type outcrop section.

The Umm er Radhuma is 458 metres (1502 feet) thick at the supplementary type well section, and comprises a very similar sequence as at the type outcrop section.

Basal Contact: The Umm er Radhuma Formation rests upon the Late Cretaceous Aruma Formation in the type well section.

The Umm er Radhuma Formation has been suggested to rest conformably upon the Late Cretaceous Tayarat Formation in the supplementary type well section. However, a widespread unconformity occurs between the Late Cretaceous and the Tertiary in Iraq, suggesting that the contact is more likely to be unconformable.

Top Contact: The Umm Er Radhuma Formation is conformably overlain by the Rus Anhydrite Formation both at the type outcrop section and the supplementary type well section.

Biostratigraphical Data: The Umm Er Radhuma Formation is generally poorly fossiliferous at the type outcrop section but in eastern Nejd and in the area of the Hasa Oil Fields benthonic foraminiferal assemblages are abundant and varied and can be used to sub-divide the Umm Er Radhuma Formation into three biostratigraphic units.

The benthonic foraminifera were used by Sander (1952) and Smout (1954) to date the

the Umm Er Radhuma as Palaeocene to Early Eocene.

Owen and Nasr (1958) have also recorded a flood of *Rotalia* sp. and *Lockhartia* sp., in the southern Kuwait area, which is locally referred to as the *Rotalia-Lockhartia* Zone. However, in the supplementary type well section in Iraq Owen and Nasr (1958) recorded a flood of *Aveolina* sp. at the top of the Umm er Radhuma Formation.

Where the Umm er Radhuma Formation outcrops in Iraq, it has been divided into two informal limestone units which form scarps in an otherwise flat desert. These limestone units are the Ghurra Beds and the Basita Beds and are described in detail below:

Ghurra Beds:

The type locality for the Ghurra Beds is on a scarp situated approximately 50 kilometers (31 miles) west of southwest of the Wagsa water wells. The locality lies about 2 kilometers (1.2 miles) southwest of the triangulation point S.85.

The Ghurra Beds are informal limestone units and are 36 metres (118 feet) thick at this locality but this is a minimum thickness as the base is not exposed. Due to this lack of exposure it has never been proven that the base of the Ghurra Beds coincides with the base of the Umm Er Radhuma Formation. The fauna is non-diagnostic and the Ghurra beds are dated as Palaeocene as they underlie the Palaeocene to "Early" Eocene Basita Beds.

Basita Beds:

This second informal limestone unit which was originally described about 18 kilometres (11 miles) southwest of Aidah where 15 metres (49 feet) is exposed. The Basita Beds contain abundant benthonic foraminifera which have been assigned to the Palaeocene to "Early" Eocene.

Ctyroky and Karim (1971) studied benthonic and planktonic foraminifera, ostracods, molluscs and brachipods from the Akashat phosphate deposits of the Umm Er Radhuma Formation of the Ga'ara area. They used this fauna to date the Umm Er Radhuma Formation as Palaeocene in age. Ctyroky & Karim were able to correlate

2.0 General Geology

The Akashat benthonic foraminiferal assemblage with benthonic foraminiferal assemblages in North Africa, Iran, Pakistan, India and Burma. They also correlated the planktonic foraminifera with similar assemblages recorded by van Bellen *et al.* (1959) and Daniel (1954), from the Aaliji Formation in northern and central Iraq and in eastern Syria. Finally, they correlated the Akashat Section with Palaeocene strata in Egypt, Palestine, Syria and more distant areas in Europe, North Africa, South Asia and North America.

Amer (1977) and Al-Muttar (1976) did not find any indication of an Early Palaeocene age in the Umm Er Radhuma Formation in the subsurface sections of the Akashat area in western Iraq.

Al-Siddiki (1978) studied subsurface sections of the Umm Er Radhuma Formation and recorded large benthonic foraminifera plus the planktonic form *Globigerina* sp.. He assigned the Umm Er Radhuma Formation to the Palaeocene without finer correlation.

In contradiction to the work of Al-Muttar (1976), Amer (1977) and Al-Saddiki (1978), Karim (1977) recorded a Danian assemblage of planktonic foraminifera from a subsurface section from around Akashat in western Iraq.

Radosevic & Lesevic (1980) in their study of outcrop and well sections from the Syrian boarder to the town of Najaf recorded benthonic foraminifera, molluscs, calci-sponges, corals, algae and echinoiderms from the Umm Er Radhuma Formation which they assigned to the Late Palaeocene to Early Eocene.

Al-Hashimi & Amer (1985) also recorded an Early Palaeocene planktonic foraminiferal assemblage from the phosphatic facies of the Umm Er Radhuma Formation in a subsurface section (Traibeel waterwell) at Traibeel border point in western Iraq. It was characterised by *Globorotalia daubjergensis*, *Gr. uncinata* and *Gr. compressa*. Based upon this evidence of a Mid Palaeocene age for the phosphatic units of the Umm er Radhuma Formation, Jassim *et al.* (1984) separated the phosphatic facies as an independent rock unit which they called the Akashat Formation.

Distribution: The Umm er Radhuma Formation in Iraq, generally crops out southwest and west of a line joining Ansab, Shabicha and Lussuf. The formation also occurs in the western and central area of Iraq, and on the western rim of the Ga'ara Depression. The basal beds of the Umm er Radhuma Formation are phosphatic in the Ga'ara area and were originally put into a separate formation, the Semhat Formation, by I.P.C. geologists. Also in the Ga'ara area, the Umm er Radhuma Formation transgresses over the pre-Tertiary outcrop of the Maastrichtian Tayarat Limestone Formation, the Cenomanian M'sad Formation and the Rutbah Sandstone Formation, on to the deeply eroded Middle Triassic Ga'ara Sandstone Formation. The Umm er Radhuma Formation is absent from southwestern Ga'ara and from the Wadi Hauran, but is encountered in all deep wells drilled west of the Nahr Umr structure.
In general, the Umm er Radhuma Formation increases in thickness eastward. On the Batn Scarp, close to the frontier with Saudi Arabia, in a composite section near Aidah, the formation is 215 metres (705 feet) thick. However, the Umm er Radhuma Formation is 437 metres (1435 feet) thick in the B.P.C. Well Ratawi No.1 and exceeds 485 metres (1500 feet) thickness in wells on the Zubair structure.

2.6.2 Rus Anhydrite Formation:

Type Section: Outcrop section from the southwest flank of the Dammam Dome below Jebel Umm Er Rus in Eastern Saudi Arabia (Lat. 26° 19.5 N, Long. 50° 10.0E).
Supplementary Type Section: B.P.C. Well Zubair No.3 (Lat. 30° 23' 01" N, Long. 47° 45' 29" E) between the drilled intervals of 815 metres (2673 feet) and 881 metres (2890 feet).
Author(s): Type section originally described by Sander (1952), while the supplementary type well section was described by Owen and Nasr (1958).
Synonym(s): "Rus Formation" of Mitchell (1956).
Lithological Characteristics/ Thickness: The Rus Anhydrite Formation is 56 metres (184 feet) thick at the type section and the formation is divided into three units, which

are described below:

(3). Top unit is 3.6 metres (12 feet) thick and comprises a white, soft, chalky porous limestone, with one or more calcarenite beds at the top.

(2). Middle unit is 31.8 metres (104 feet) thick and comprises light coloured marls with local, irregular masses of crystalline gypsum and occasional thin harder limestone beds. Quartz geodes also occur at several levels.

(1). Basal unit is 21.0 metres (69 feet) thick and comprises a grey to buff compact crystalline limestone with minor amounts of soft limestone, made porous by leaching of small organic remains. Quartz geodes occur rarely in the lower part but are more typical of the uppermost part of this unit.

The Rus Anhydrite Formation is variable, for example two common equivalents of the middle unit are either a white, compact, finely crystalline anhydrite with interbedded green shales and minor amounts of dolomitic limestone, or grey marls with coarsely crystalline calcite and interbedded shale and limestone.

The Rus Anhydrite Formation from the supplementary type well section consists of a sequence of hard, dense and massive anhydrites with some unfossiliferous limestones, and a few blue shales and marls.

Basal Contact: At the type outcrop section and the supplementary type well section the Umm Er Radhuma Formation rests conformably upon the Rus Anhydrite Formation. At the type outcrop section the contact is marked at the top of a dolomite unit containing *Lockhartia tipperi* Davies of the Umm er Radhuma Formation. This is overlain by a light coloured, soft, dolomitic limestone commonly containing leached indeterminate moulds of small molluscs of the basal Rus Formation.

Top Contact: At the type outcrop section, the Rus Anhydrite Formation is overlain by the Dammam Limestone Formation. The top of the Rus Anhydrite Formation is recognised by the top of the light coloured arenite layers, this is overlain by the basal unit of the Dammam Formation which comprises thinly bedded impure limestones and shales containing rare mollusc remains.

In the supplementary type well section described above the Rus Anhydrite Formation is disconformably overlain by the Dammam Limestone Formation. However, van Bellen *et al.* (1959) described the contact between the two formations as being unconformable, based on observations at the supplementary type section and on other well sections and outcrop sections in the area. He also noted a grey to green shale approximately 2.5 metres (8 feet) thick at the base of the Dammam Limestone Formation in many well sections, which he took to indicate a possible unconformity. Steineke, Bramkamp and Sanders (1958) also mentioned grey and green mudrocks, possibly part of the same unit, in outcrop sections of the middle part of the Rus Anhydrite Formation, in Eastern Saudi Arabia. They explained this occurrence as a lateral variation in lithology. No indication of a similar unconformity in outcrop sections was found by van Bellen *et al.* (1959), but Ramsden and André (1953) noted that the lower Huweimi (chalk) Beds of the Dammam Limestone Formation, contain white or pinkish chalks with a freshwater appearance which also contain lamellibranchs. However, the upper Huweimi (limestone) Beds, also of the Dammam Limestone Formation, are definitely representative of a marine shoal limestone as they contain nummulites. Thus, there may be a prominent facies change between the lower and upper Huweimi Beds indicating an unconformity.

Biostratigraphical Data: The Rus Anhydrite Formation contains no diagnostic fossils, and therefore the formation is dated by its relative stratigraphic position. In the type section the Rus Anhydrite Formation has been given an inferred "Early" Eocene date. The same date was also applied by van Bellen *et al.* (1959) for the supplementary type section in Iraq, but Owen and Nasr (1958) working on the same supplementary type section inferred a "Mid" Eocene date for the Rus Anhydrite Formation.

Distribution: The Rus Formation is known from all wells in the southern Iraq area except those drilled on the Nahr Umr structure, where it is absent due to a lateral change in lithology.

2.6.3 Dammam Limestone Formation:

Type Section: Outcrop section from the rim-rock of the Dammam Dome, 2 kilometers (1.2 miles) N.85°W. of Jebel Umm er Rus (Lat. 26° 17.3' N, Long. 50° 07.7' E) in

eastern Saudi Arabia; Steineke, Bramkamp & Sander (1958) and van Bellen (1959).
Supplementary Type Section: B.P.C. Well Zubair No.3 in the Basrah area of Iraq, between the drilled intervals of 590 metres (1935 feet) and 814 metres (2673 feet).
Author(s): Type section originally described by Sander (1952), while the supplementary type well section was described by Owen and Nasr (1958).
Synonomy(s): "Dammam Formation" and the "Terme de Radhuma" of Mitchell (1956), and the "Dammam Formation" of Owen and Nasr (1958).
Lithological Characteristics/ Thickness: The Dammam Limestone Formation consists of light chalky, marly or clayey dolomitic limestones which can be divided into six units at the type section based upon the benthonic foraminifera they contain. Overall the Dammam Limestone is 27.9 metres (92 feet) thick at the type outcrop section.
The supplementary type well section consists of a sequence of whitish to grey, porous, dolomitized limestones, nummulitic limestones and soft chalky limestones. A grey to green waxy shale body is encountered at the base of drilled sections. Overall the Dammam Limestone Formation is 225 metres (738 feet) thick at the supplementary type section. Based upon the fossil content and lithologies Owen & Nasr (1958) split the Dammam Limestone Formation into four members.
However, the Dammam Limestone Formation was split even further into ten informal field units Huber and Ramsden (1945) for field mapping purposes. Theses units include: Tuqaiyid Beds, Ghanimi Beds, Barak Beds, Rudhuma Beds, Chabd Beds, Shawiya Beds, Huweimi Beds, Shabicha Beds, Sharaf Beds and Wagsa Beds. These beds were later combined by Ramsden and André (1953) to form four informal mapping units. These four informal mapping units are described below in descending stratigraphic order:
(4). Tuqaiyid/ Ghanimi/ Barak/ Rudhuma Beds - This unit consists of bryozoan-peneroplid limestones and shelf limestones.
(3). Chabd/ Shawiya/ Huweimi (limestone) Beds - This unit comprises a nummulitic limestone.
(2). Huweimi (chalk)/ Shabicha/ Sharaf Beds - This unit consists of alternating chalks and chalky limestones. The latter contain poorly preserved lamellibranchs, while the former are white or pinkish in colour and have a freshwater appearance.

(1). Wagsa Beds - This unit comprises a chalky limestone that is moderately fossiliferous and contains *Operculina libyca* Schwager.

These units described above can be recognized in the field but, they cannot be differentiated in any well sections containing the Dammam Limestone Formation further towards the east.

Basal Contact: The Dammam Limestone Formation unconformably rests upon the Rus Anhydrite Formation at both the type outcrop section and the supplementary type well section.

Top Contact: The Dammam Limestone Formation is overlain unconformably by the slightly sandy, compact limestone of the basal Hadrukh Formation at the type outcrop section in eastern Saudi Arabia. However, the Dammam Limestone Formation is overlain unconformably by the "Mid" Miocene Ghar Formation at the supplementary type well section in Iraq.

Biostratigraphical Data: At the type outcrop section the Dammam Limestone Formation has been given a Lutetian (Middle Eocene) date based on its characteristic fauna, and the lower 8.9 metres (30 feet) of the Dammam Formation has been given a Ypresian (Lower Eocene) date based on an *Aveolina*-bearing fauna described by Sander (1952). At the supplementary type well section the Dammam Limestone Formation has been given a Mid Eocene date. However the presence or absence of the late Early Eocene and the Late Eocene have not been proved in the supplementary type well section.

Distribution: The Dammam Formation appears in outcrop sections and in all deep wells in southern Iraq. In general it outcrops in a northwest-southeast belt of about 125 kilometers (78 miles) width, between the outcrop area of the Umm er Radhuma Formation to the southwest, and that of the Dibdibba Formation and the Lower Fars Formation to the east and northeast.

As part of their microfacies studies for the Tertiary of Iraq, Al-Hashimi and Amer (1985) recognised 5 planktonic foraminiferal zones and 5 benthonic foramininferal zones for the Paleocene to Early Eocene formations mentioned above based on subsurface and outcrop samples from a wide area of southern Iraq (see Figure 2.15).

2.6.4 Studied Well Sections:

This group of formations was sampled entirely within one well section in southern Iraq, Rachi No. 1.

Rachi No. 1: The Umm Er Radhuma Formation is 449.7 metres (1499 feet) thick. The Umm Er Radhuma Formation rests probably unconformably upon the Tayarat Limestone Formation, and is overlain probably conformably by the Rus Anhydrite Formation. The Rus Anhydrite is 198 metres (660 feet) thick and is conformably overlain by the Dammam Limestone Formation. The Dammam Limestone Formation is 219.9 metres (733 feet) thick and is unconformably overlain by the Abu Ghar Formation.

2.6.5 Regional Lateral Equivalents:

Following Beydoun (1989), the Umm Er Radhuma, Rus Anhydrite and the Dammam Limestone Formations can be correlated with lateral equivalents in adjacent regions. In southeastern Turkey this group of formations can be correlated with parts of the Germav, Sinan, Kayakoy, Terbuzek, Beciraman, Ur Antak and Gercüş Formations. In southwestern Iran correlation can be made parts of the Pabdeh, Kashkan, Amiran, Talehzang, Shahbazan, Sachun and Jahrum Formations. This group of formations is also equivalent to the Aaliji, Khurmala Limestone, Sinjar Limestone, Kolosh Clastics, Jaddala, Avanah Limestone, Pila Spi Limestone and Gercüş Red Beds Formations of northern Iraq. It also equivalent to the Umm Er Radhuma, Rus Anhydrite and Dammam Limestone Formations in Kuwait, Saudi Arabia, Qatar and Abu Dhabi, with the addition of the Pabdeh Formation in the United Arab Emirates. This group of formations is also equivalent to the Aaliji, Tyron, Jaddala, Sinjar, Midyat Formations and the Araq Flint Member in Syria. In Jordan, the Taqiye, Sara and Maan Formations are equivalent to this group of formations. This group of formations also has unnamed equivalents in Lebanon, and is equivalent to the Shephela Group (Taqiya and Sara Formations) in Israel.

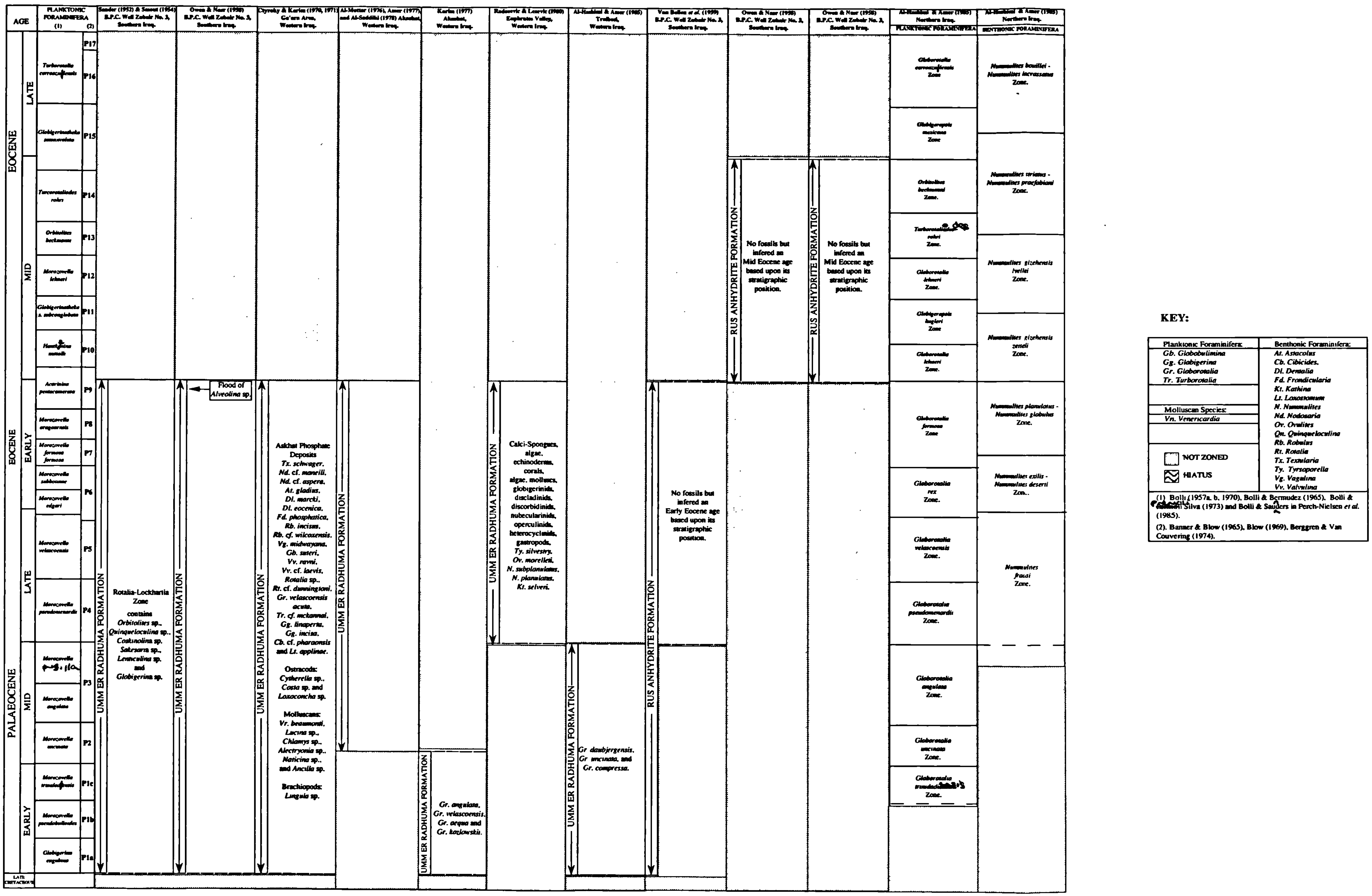
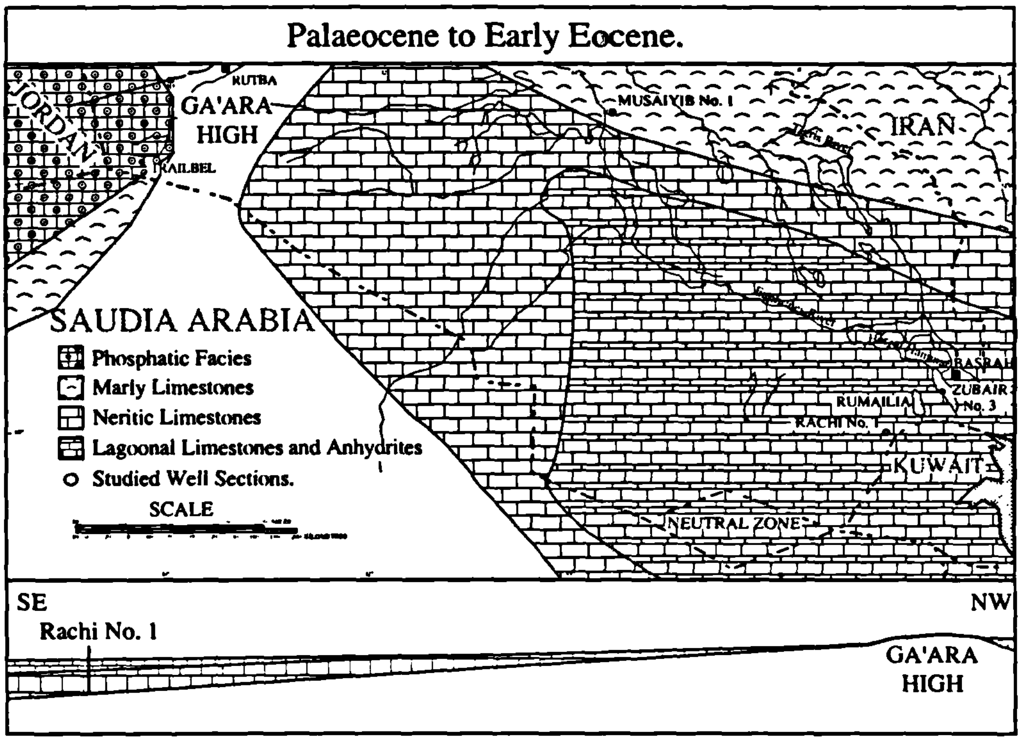


Figure 2.15 Previous Biostratigraphic Work for the Palaeocene to Mid Eocene Succession of Southern Iraq.

2.6.6. Sedimentology and Depositional History:

The sedimentology and depositional history for this time interval is based upon van Bellen *et al.* (1959), Buday (1980) and Al-Hashimi and Amer (1985) and Beydoun (1989) and is illustrated in Figure 2.16. The Palaeocene to Early Eocene succession was established during a marine transgression following the Laramide Orogenic movements at the Cretaceous/ Palaeocene boundary. In southern Iraq and northern Iraq this causes the Palaeocene to Early Eocene succession to be deposited unconformably on the Late Cretaceous succession. The Palaeocene to Early Eocene succession in Iraq comprises nummulitic limestones of the Umm Er Radhuma Formation, which are deposited on a shallow shelving area south of the Ga'ara High, virtually covering all of southern Iraq and continuing over Kuwait and the eastern part of Saudi Arabia. Ibrahim (1979) noted the occurrence of a graben in southern Iraq on the shallow shelving area that trends north-south, and runs south from the village of Ganmi through Kuwait into Saudi Arabia. He called this graben the Dibdibba Graben. The M.P.C Well Rachi No. 1 sampled during this study occurs on the eastern margin of this graben. It is believed that the sediments of the Umm Er Radhuma Formation become more open marine in nature towards the east. As explained earlier, on the northwestern flank of the Ga'ara High cherty phosphatic marls and neritic littoral limestones developed, similar in some respects to the Aaliji and Sinjar Limestone Formations from the northern Iraq area, but these form the Akashat phosphatic deposits part of the Umm Er Radhuma Formation. The phosphatic nature of the sediments indicates the sediments were also most likely laid down in a oxygen deficient reducing environment. At the end of the Early Eocene in the northern Iraq the Van phase of the Laramide Orogeny caused unconformable relationships to be established between the Paleocene to Early Eocene succession and the Mid to Late Eocene succession. In southern Iraq it is believed that these orogenic movements did not interrupt sedimentation but did cause facies changes. This resulted in the deposition of the Rus Anhydrite Formation caused by the more restricted access to open marine conditions. A major marine transgression followed the deposition of the Rus Anhydrite Formation and the nummulitic and marly limestones of the Dammam Limestone were deposited over the wide shallow shelving area of southern Iraq,



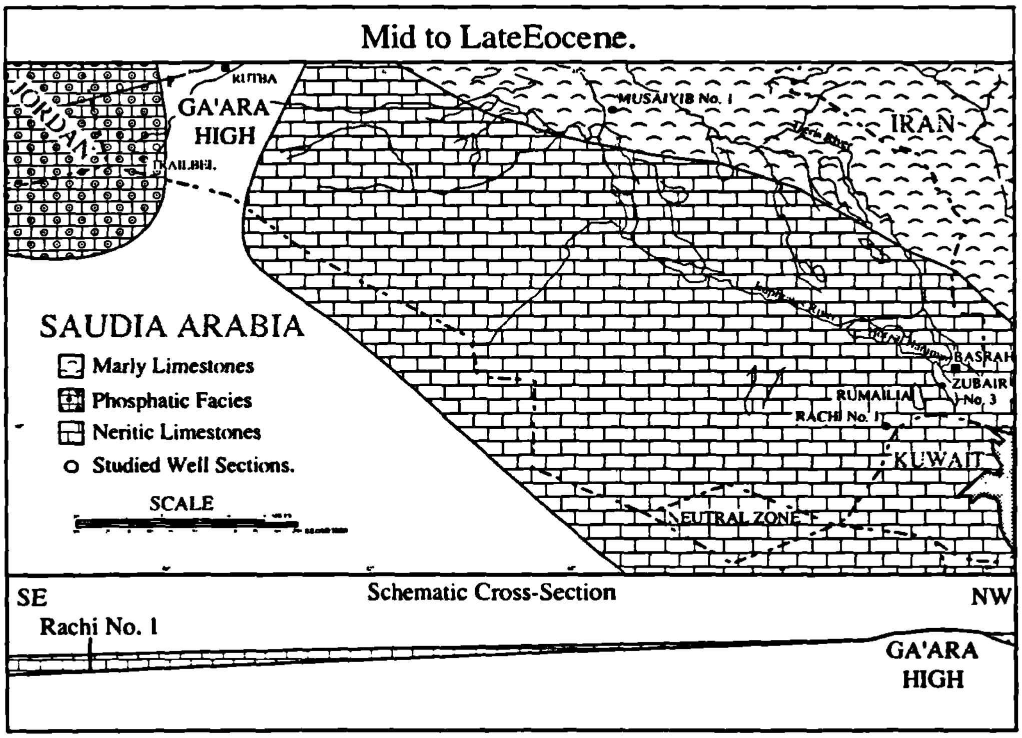


Figure 2.16 Facies Map for the Palaeocene to Late Eocene of Southern Iraq (Modified after Buday, 1980).

Kuwait and eastern Saudi Arabia. Deposition during in the Late Eocene was terminated by the Pyrenean Orogeny. There are no southern Iraqi equivalents to that of the Oligocene succession as the narrow basin collecting the sediments in northern Iraq re-established itself to the north of the Ga'ara High.

During the study of the Palaeocene to Early Miocene succession in Iraq it was necessary to locate the boundaries of this succession in each well section studied. In carrying out this requirement the top of the Cretaceous and the base of the Mid Miocene was sampled. The Cretaceous formations sampled include the Shiranish, Tanjero Clastics, Pilsner Limestone and the Tayarat Limestone Formations. The Mid Miocene formations encountered include the Lower Fars (Transition Beds and Basal Conglomerate) and the Abu Ghar Formations.

CHAPTER THREE
TECTONICS AND STRUCTURE

3.1 Tectonic Evolution:

This account of the tectonic evolution of Iraq is based upon Hempton (1987), Beydoun (1988), Beydoun *et al.* (1992), Beydoun & Sikander (1992) and Buday *et al.* (1980). The study area forms part of the Arabian Plate which comprises the Arabian Peninsula, southeastern Turkey and southwest Iran. The Arabian Plate in turn formed part of the African Plate throughout much of its geological history, and was referred to as the "Arabian Promontory" by Beydoun (1988). Three major episodes have occurred during the plate tectonic history of Iraq and the surrounding area and these event are now outlined below and are summarized in Figure 3.1.

3.1.1 Late Proterozoic to Mid Eocene: Following the accretion and consolidation of the basement complex mainly in the unit Late Proterozoic, the tectonic history of the plate after this event is remarkably stable until Mid to Late Eocene times, with only two notable tectonic events occurring in the Permian to Triassic and the Late Cretaceous:

(1). **Permian to Triassic:** This tectonic events involved the break-up of Pangaea and the separation of Gondwana by the process of passive rifting. This occurred approximately along the line of the Taurus-Zagros mountains in the north and northeast, allowing stretching of the frontal edge of the Arabian Plate.

(2). **Late Cretaceous:** This tectonic events involved a short-lived convergence which resulted in obduction and thrusting of plate material and the failed closure of Tethys. These movements were the result of the Laramide orogeny.

During the Palaeocene to Early Eocene the Arabian Plate as part of the African Plate continued to move northward towards Eurasia as the oceanic crust between the continental plates was subducted beneath Eurasia.

3.1.2 Mid Eocene to Early Miocene: During the Mid to Late Eocene (45-36 Ma.) the northwest corner of the "Arabian Promontory" collided with Eurasia at the Turkish block and spread along the northeastern margin. This plate collision

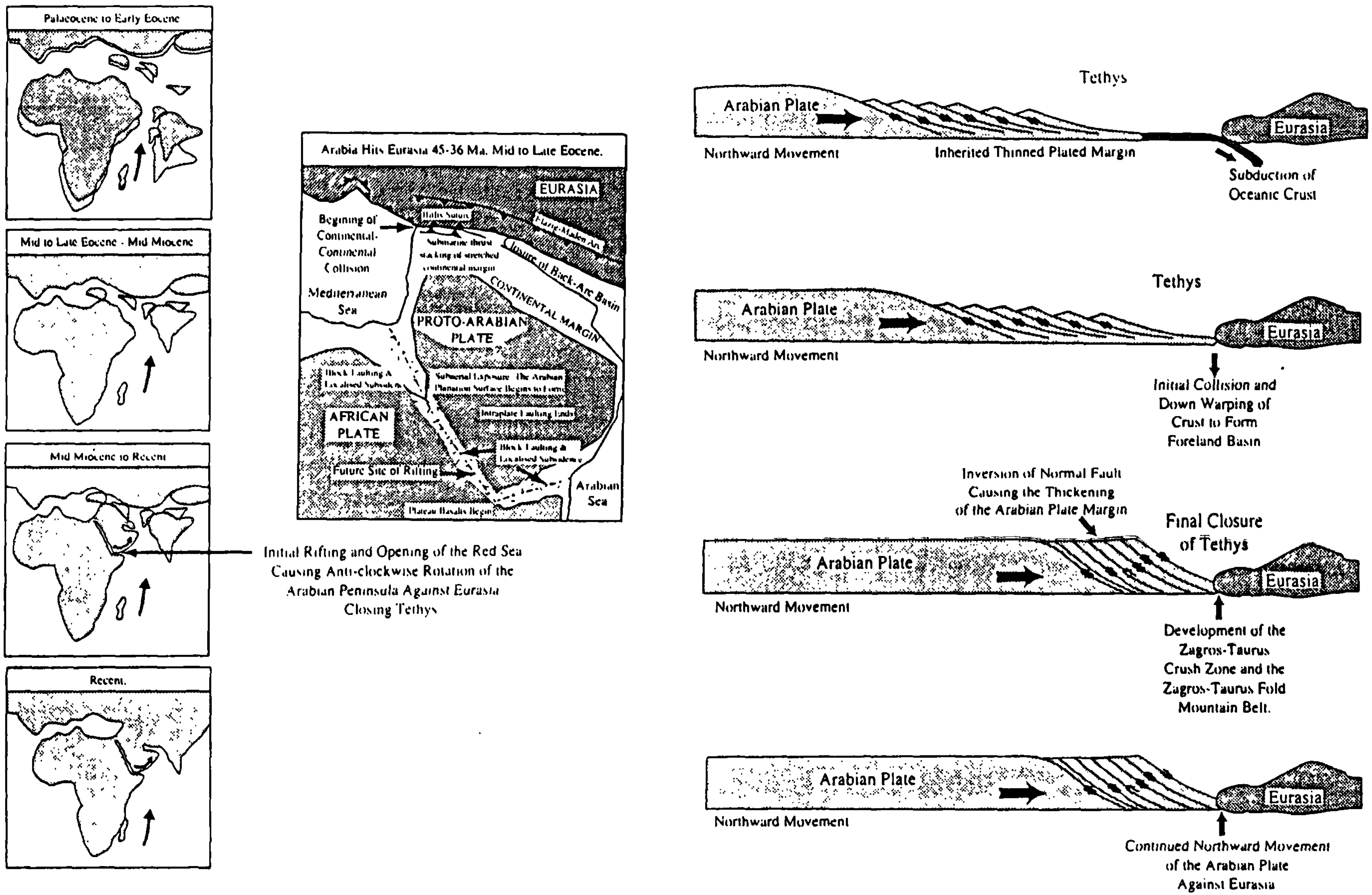


Figure 3.1 The Developments and Timing of the Major Tectonic Events Affecting the Middle East and Surrounding Area During the Palaeocene to Recent (Modified After Hempton 1987, Scotese *et al.* 1988, Beydoun *et al.* 1992).

established a foreland basin between the plates which restricted marine sedimentation to the northeast margin of the Arabian Plate during the Oligocene to Early Miocene. This accounts for the absence of Oligocene to Early Miocene pelagic sediments in southern Iraq. The restriction of sedimentation was primarily the result of tectonics but was accentuated further by the global sea-level fall in the Mid Oligocene. Gawarecki and Schamel (1986) also noted that sea-level and tectonics had a combined effect in Iraq and that the major sedimentary cycles from the Triassic to the Tertiary could be correlated with high sea level stands identified by Vail *et al.* (1977). They also suggested that during the majority of this period tectonic processes played a less important role in providing sedimentary sources and restricting sedimentation to basins. The periods Gawarecki and Schamel noted the effects of tectonic processes are when the Tethys basin tried to close during the Late Cretaceous and when the movement were reactivated during the Mid to Late Miocene.

3.1.3 Mid Miocene to Present: The convergence of the Arabian and Eurasian plates occurred during Mid Miocene to Early Pliocene as a result of the two-stage opening of the Red Sea and the Gulf of Aden at 10 Ma. and 5 Ma. . This two-stage opening caused closure of the trough connecting the Mediterranean and the Arabian Gulf as the result of seafloor spreading mainly during the second stage (5 Ma.). This resulted in the anti-clockwise rotation of the Arabian Plate against the Eurasian Plate and the final suturing of the two continents along the Taurus-Zagros crush zone. In the early stages of closure, during the Mid Miocene the basinal area was unstable and began to break-up to form a series of smaller sub-basins. In these smaller sub-basins restricted sediment types including evaporites were deposited. The sub-basins were eventually closed by the continuing converge of the two plates later on. The final closure of Tethys was sufficiently powerful to generate the Taurus-Zagros mountain range and to the develop of the predominantly northwest-southeast structural trend, the southwest verging reverse faults and spectacular whaleback anticlinal folds. During the convergence of the Arabian and Eurasian plates the stretched thinned Arabian Plate margin, inherited from the Permian to Triassic passive rifting phase of Gondwana became thickened. This was the result of the reactivation of the original extentional faults in a reverse manner. The thickening process of the Arabian Plate margin is not universally accepted and Le Pichon (1968), Nowroozi (1972), McKenzie (1972), Buday (1980), Masin (1980) and Ni and Barazangi (1986) all favoured subduction of plate material under Eurasia instead. Finally, the transpressional forces of the convergence that resulted in the development of the Taurus-Zagros suture were translated into a dextral strike slip movement. This dextral strike slip movement is still active to the present day, as convergence between the Arabian and Eurasian plates continues.

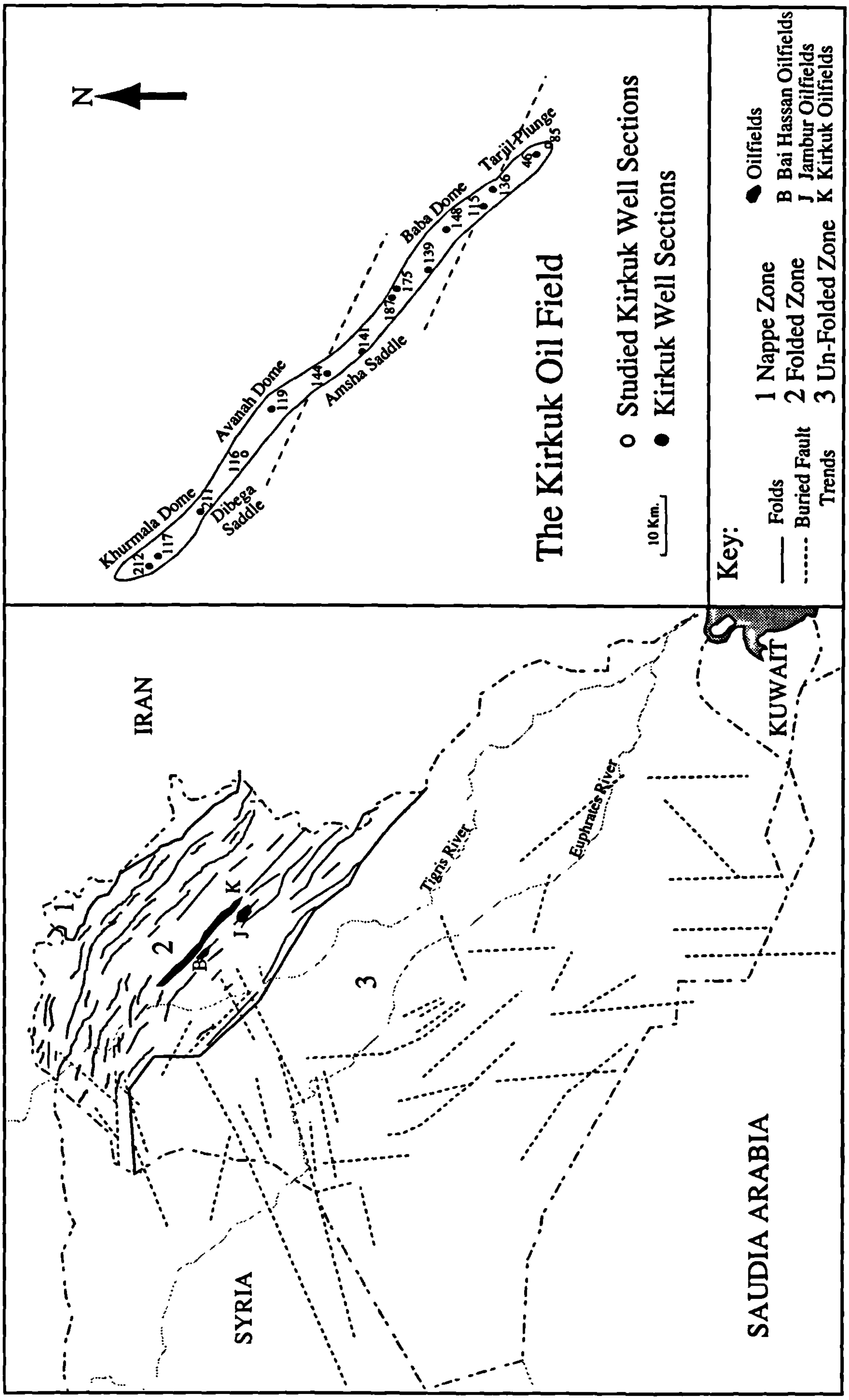
3.2 Tectonic Framework:

Dunnington (1958), noted many previous works including Henson (1951a), De Boeckh, Lees and Richardson (1929), Lees and Richardson (1940), and Lees (1950a, b, 1951, 1953), when he put forward the tripartite structural division of Iraq. The three zones he recognised are: the nappe zone, the folded zone and the un-folded zone, which occur along the dominant northwest-southeast trend of the Zagros mountains formed during the Alpine Orogeny (see Figure 3.2). The zones are discussed in detail below:

(1). **Nappe Zone:** This zone occurs in the extreme northeast of the study area and comprises two major thrust faults dipping towards the northeast, which resulted from three phases of southwest thrust movements during the Late Cretaceous to Pliocene (Stocklin, 1974).

(2). **Folded Zone:** This zone is approximately 100 miles wide and contains large anticlinal folds that trend east-west in the north and northeast-southwest in the south following the Zagros trend. These folds tend to increase in tightness towards the nappe front, and in some cases the most northeasterly folds are overturned. However, this general rule has exceptions with some relatively tight folds occurring away from the nappe front, for example the Hamrin North, Makul and Sinjar anticlines are high angle structures relative to neighbouring flat lying anticlines. This phenomenon of tight folds next to shallow folds was explained by Henson (1951b) as being related to a pre-existing fault complex that could buttress or deflect the effects of the tangential pressures that caused the folding in the Late Tertiary.

(3). **Un-Folded Zone:** The boundary between the folded and un-folded zone is generally abrupt, however the un-folded zone is not strictly un-folded as there



3.2 Structure of Iraq in particular the Kirkuk Oil Field.

are two large folds in this zone: a gentle broadly domed fold that trends east-west in the Ga'ara area, and a narrow but gentle fold that also trends east-west in the Anah area. The folding in the Ga'ara area is thought to represent basement arching and the folding in the Anah area is thought to represent fault movements. The un-folded zone also possess many buried folds and faults which predominantly trend in a north-south, east-west, northwest-southeast and northeast-southwest manner and are the result of complex movements during tectonism. Some of the fault trends are very long and have been traced into southern Iraq and Syria.

Al-Juwaily and Domaci (1976), Al-Rawdi (1978, 1984), Numan (1984), Zwain (1984) and Naoum (1989) noted the importance of the block faulted basement upon the structural development of the study area. The block faulted basement was believed to be the result of the release of stress, and the migration of the stress field during the plate collision in the Late Tertiary. The block faulted basement caused the re-orientation of fracture systems in single folds and even rotated sets of folds and their associated fracture systems in some cases, as the result of tangential pressures in the later stages of the collision between the Arabian and Eurasian plates.

3.3 Structure of Studied Sections:

The well sections studied in Iraq do occasionally penetrate large structures (see Figure 3.2). The structures affecting the well sections sampled are described in detail below:

(1). **Kirkuk No.s 85 and 116:** These wells penetrate the Kirkuk structure which is a sinuous anticline that is 60 miles long, trends northeast-southwest, and is made up of two saddles (Dibega and Amsha) and three domes (Khurmala, Avanah, and Baba). The I.P.C. Well Kirkuk No. 85 is located on the Tarjil Plunge on the extreme southeast end of the Kirkuk Anticline, while the I.P.C. Well Kirkuk No. 116 is located on the southern limb of the Avanah Dome.

(2). **Bai Hassan No.s 8 and 10:** These wells penetrate the Bai Hassan Anticline which lies parallel to the Kirkuk structure just 6 miles southwest; it trends northwest-southeast, and is around 20 miles long.

(3). **Jambur No. 4:** This well section penetrates the Jambur Anticline, which trends northeast-southwest and lies almost in-line with the Bai Hassan Anticline which some 45 miles towards the southeast. The Jambur Anticline lies parallel to the Kirkuk Anticline and the Pulkhana Anticline is off-set from them both, that is the folds are en-echelon.

(4). **Pulkhana No. 5:** This well section penetrates the Pulkhana Anticline which is around 50 miles long, sinuous, asymmetrical towards the southwest and generally trends northwest-southeast.

(5). **Atshan No. 1:** The well section is located on the Atshan Anticline which is a small relatively straight anticline, approximately 30 miles long, trending northwest-southeast.

(6). **Chemchemal No. 2:** This well section is located in the northeast of Iraq within Chemchemal Subzone of the Foothills Zone of Buday (1980). The Foothills Zone comprises narrow, tight anticlines separated by board, open synclines.

(7). **Musaiyib No. 1 and Rachi No. 1:** The structures effecting these well sections are unknown as they are obscured by sedimentary cover, but are located within the unfolded zone of Iraq.

CHAPTER FOUR
METHODOLOGY

4.1 Introduction:

This chapter will deal with the selection and preparation of samples and how subsequently the samples were analysed.

4.2 Sampling Strategy:

In all 515 samples comprised of drill cuttings, conventional cores and bit samples were sampled from ten well sections currently stored at Reading University core store. The samples were selected using stratigraphic information gathered from the Iraq Petroleum Company (I.P.C.), British Petroleum Company Limited and published sources (van Bellen *et al.*, 1959). The final selection of wells and samples was based upon three criterion:

1. The Availability and Type of Material - Material was occasionally missing from sampled sections held at Reading, and these wells were avoided. Generally, conventional core material was preferred to drill cutting samples to eliminate the effects of caving.

2. The Thickness of a Well Section - The thickest well sections for each formation requiring sampling were generally taken as they would provide more samples for the study, therefore offering a greater probability of finding calcareous nannofossils if they are present.

3. Geographical position of the Well Section - The location of the well sections was also taken into account, because the widest geographic distribution possible was sought for the well sections in Iraq to provide a truly nationwide correlation.

The well sections and the formations sampled for this study can be seen in Figure 4.1 and listings of the samples taken from all of the 10 well sections can be found in Appendix A.

4.3 Preparation Techniques:

The Light Microscope (LM) and the Scanning Electron Microscope (SEM) were used to view preparations of drill cuttings, bit samples and core material. Drill cuttings and

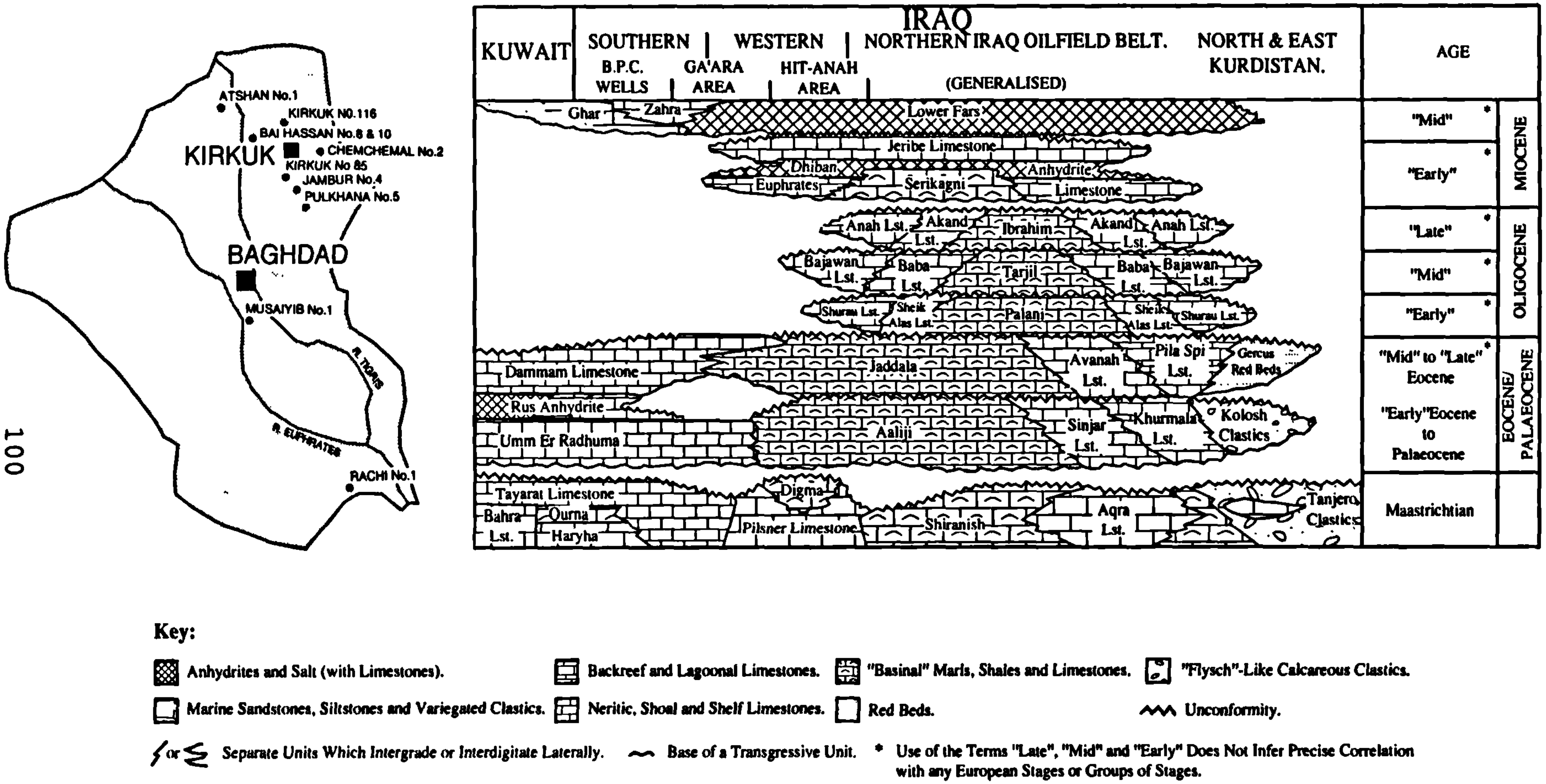


Figure 4.1 Location Map of the Well Sections and the C[illegible]stratigraphy Studied for the Late Cretaceous to "Mid" Miocene Period in Iraq (Partly after Van Bellen *et al.*, 1959).

bit samples were prepared by taking small, yet representative, sub-samples and placing them in separate test tubes. A few drops of distilled water were added and the material lightly crushed with a glass rod. Glass slides were then prepared by polishing and labelling them using a diamond tipped pen. The slides were then placed on a hot plate operating at a temperature of 50 - 100°C. By cleaning the slides in this manner, grease is removed and problems with surface tension of the suspension on the slide reduced. The tube was shaken and, using a disposable pipette, 3-4 drops of suspension were placed on the first slide and was evenly spread by using the dropping end of the same pipette, removing any excess suspension. The slide was then returned to the hotplate to dry. A second slide was prepared in exactly the same way as a back-up in case of accidental damage and for use in archiving. However, even though great efforts were made to insure the even spread of the suspensions on slides, in some cases the sediment flocculated on drying. In these cases one drop of distilled water was put on the slide and the dried sediment was re-suspended and redistributed evenly on the slide once more, using the dropping end of the disposable pipette. Once dried the slides were removed from the hotplate and placed on tissue paper to avoid contamination while the coverslip was prepared for fixing onto the slides. Three drops of Norland Optical Adhesive (Refractive Index 1.56) were placed along the length of the rectangular coverslip (25 X 50mm), and was positioned on each slide. The adhesive was then allowed to spread evenly between the two surfaces before it was hardened under an ultra-violet lamp for 20 minutes. Finally, the slide was washed, dried and labelled with adhesive labels ready for examination under the LM. Some samples of the I.P.C. Well Atshan No.1 (165-170', 195-200', 225-230', 285-290', 375-380', 405-410' and 1460-1465') needed pre-treatment before the method could be applied as the drill cuttings were coated in bitumen, which made the spreading of a suspension of the sediment onto a glass slide difficult. Therefore, small subsamples of the drill cuttings were taken and put into glass vials, which were then filled with acetone. The contents of the glass vials were then shaken at 5 minute intervals over then next 30 minutes. After 30 minutes each subsample was taken in turn and poured onto a piece of filter paper, allowing the acetone to evaporate. Once the acetone had evaporated the cleaned, dry subsample was placed in a glass test tube ready to undergo the normal procedure for the preparation of drill cuttings described above. This pre-treatment was successful in removing enough bitumen to facilitate the even distribution of a suspension of the subsample onto a glass slide.

Core material was prepared by selecting a core chip and scraping the outer surface clean using a scalpel blade, this was done to minimize the effects of contamination. The clean core chip was removed and crushed in a fresh piece of folded tissue paper using a hammer. The crushed material was then placed in a test tube, and was treated in the same way as the drill cuttings and bit samples to produce slides for examination under the LM.

The SEM slide preparations were prepared following the standard techniques outlined in Lord *et al.* (1982). This involved preparing a sample in the same way as for an LM preparation up to just before spreading the suspended solution on a glass slide. The suspended solution was then centrifuged to remove excess clay particles and to concentrate the calcareous nannofossils in the sample. The centrifuge technique involves two stages:

Stage 1. The suspended solution is shaken and placed in a centrifuge set at 300 rev/min for 15 secs. The suspended solution (supernatant) was carefully decanted and the sediment plug was discarded.

Stage 2. The suspended sediment from Stage 1 was topped with distilled water and shaken up, and was again placed in the centrifuge set at 1000 rev/min for 30 secs. This time the supernatant was discarded and the sediment plug was resuspended with distilled water.

Stage 2 of the centrifuge technique was continually carried out until the supernatant was clear, then the sediment was resuspended ready for the next stage of the preparation process. Next a circular coverslip (13mm diameter) was placed on a hotplate at an operating temperature of 100°C and one drop of the final centrifuged sediment suspension, was placed on the coverslip and allowed to dry. While the coverslip was drying, a SEM stub was prepared by spreading colloidal silver on the top surface of the stub. Once dried the coverslip was taken off the hotplate and placed on top of the colloidal silver, on the top surface of the stub, so that the sediment on the coverslip was uppermost. The stub was then put into a holder in a box over night. The lid of the box was propped slightly open and a tissue was placed over the box so that fumes from the drying colloidal silver could escape to dry ensuring that no dust particles in the atmosphere could settle on the coverslip contaminating it before it was gold coated. The stub is then placed in a sputter coater unit and coated with a thin layer of gold just prior to inspection under the SEM.

The L.M. was the primary tool used during this study as taxa could be reliably identified even if poorly preserved, as was often the case. The material sampled to produce the slides was returned to the archives at Reading University and the well logs used to sample this material were returned to I.P.C. and BP Exploration. The slides produced during this study have been deposited in the slide archive, and the film/ frame numbers on the plates refer to the film archive, both of which are housed in the Micropalaeontology Unit at University College London.

4.4 Biostratigraphic Techniques:

A majority of the samples are drill cuttings but some core and bit samples were also analysed. The core was poorly collected when the wells were originally drilled. These factors have made it possible only to use the First Downhole Occurrence (F.D.O's) of taxa reliably. Initally, presence/ absence records were used so that familiarity with the material could be established. Later on, more quantitative techniques were employed. This involved the counting of 300 or more nannofossil occurrences (where possible) per slide in the LM, and noting the number of fields of view it required to count that number. This figure was recalculated as the number of nannofossils per field of view, which helps to establish the relative overall abundance rating for the sample. The abundance ratings and the corresponding number of nannofossils per field of view are listed below:

4.0 Methodology

Abundance Rating	No. of Nannofossils per Field of View
Very Low	<1.0
Low	1-10
Moderate	>10-20
High	>20-30
Very High	>30

The general state of preservation of the nannofossil assemblage being counted was noted in the LM following the preservation scheme of Roth and Thierstein (1973) with some modifications by Roth (1983). This scheme puts a number on the amount of overgrowth and etching that effects the nannofossil assemblage. This can be in the form of primary dissolution at the sediment/ water interface or secondary dissolution and/ or overgrowth during diagenetic rock forming processes. The preservation scheme is outlined below:

- **E-3** Heavily etched assemblage. Large amounts of fragmental material only dissolution resistent species remain.
- **E-2** Moderately etched assemblage. Nannofossil species possess irregular outlines and delicate structures dissolved. Also the more delicate species are absent due to dissolution.
- **E-1** Slightly etched assemblage. Nannofossil species possess serrated outlines and delicate structures are slightly dissolved.
- **X** Excellent preserved assemblage. Nannofossil assemblage shows no signs of overgrowth or etching.
- **O-1** Slightly overgrown assemblage. The coccoliths making up the nannofossil assemblage have slightly extended elements and slightly thicker cross bars.
- **O-2** Moderately overgrown assemblage. The coccoliths making up the nannofossil assemblage have extended elements and the central area of the coccoliths are is obscured.
- **O-3** Heavily overgrown assemblage. The coccoliths making up the assemblage are totally overgrown making accurate identification difficult.

In most samples studied both etching and overgrowth were evident but it is usually possible to identify the most dominant process affecting the nannofossil assemblage.

Abundance charts were drawn up to assess whether abundance peaks in certain species or groups of species could be mapped over an area, and to help locate and quantify the amounts of reworking and caving that occurred in individual wells.

4.0 Methodology

Reworking was identified in four ways:

(1). When a much older species occurred with much younger species, e.g *Watznaueria barnesae* (Cretaceous) found in the same sample as *Fasciculithus tympaniformis* (Mid to Late Palaeocene).

(2). Reworked nannofossils tend to be poorly preserved and have ragged outlines.

(3). Reworked nannofossil assemblages tend to possess large proportions of robust species as do assemblages that have suffered the effects of dissolution. Thierstein (1980) made a study of solution susceptibility of Cretaceous and early Tertiary calcareous nannofossils, which forms the basis for the observations in this study.

(4). Reworked occurrences of taxa may cause abundance peaks that are not generally sustained.

Caving is present in drill cuttings where material from higher in the well has fallen down hole and becomes incorporated within a sample in the drill mud. This kind of contamination is generally accepted as it is difficult and time consuming to eliminate. However, contamination in conventional core from drill muds is relatively quickly and easily eliminated as the actual rock is sampled which can be scrapped and washed clean.

Caving in samples is detected in two ways:

(1). When a younger calcareous nannofossil species is detected in an older species making up a zone, for example when *Discoaster kuepperi* (Early Eocene) occurs with *Fasciculithus tympaniformis* (Mid to Late Palaeocene).

(2). On the abundance diagram a sharp unsustained (occasionally large) peak occurs below a well established true occurrence peak of a particular species or group of species. This former peak is believed to indicate caving.

How "true", "reworked" and "caved" occurrences can be detected on abundance diagrams is shown in Figure 4.2. Detecting reworking and caving is difficult when a species or group of species is common as it is difficult to assess which peak is significant, and this is why individual peaks in abundance could not be correlated over the study area. However, this method has proved very useful in locating accurate

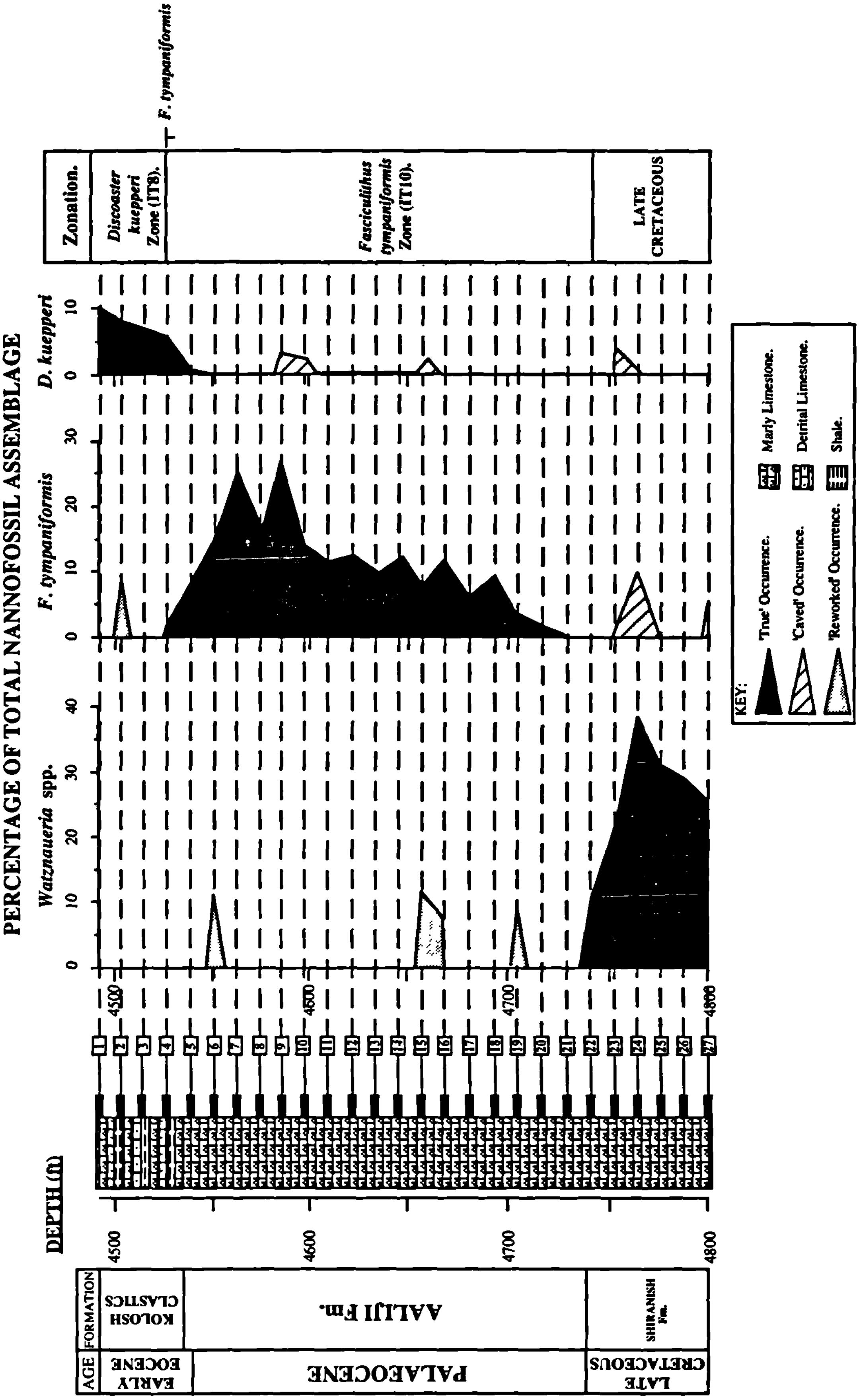


Figure 4.2 Schematic Abundance Diagram Illustrating 'True', 'Caved' and 'Reworked' Occurrences.

4.0 Methodology

F.D.O's for marker species, when used in conjunction with the other information to establish the zonation scheme for the study area.

The marker species used in the calcareous nannofossil zonation scheme in Iraq were selecting using general biostratigraphic guidelines which are listed below:

(1). The marker must have a distinctive first or last occurrence that can be correlated over many sections.

(2). The marker species must be easily identifiable in the light microscope.

(3). A marker species should be a reasonably common constituent of the total nannofossil assemblage.

(4). The marker species should be geographically widespread and preferable have a cosmopolitan nature.

Points 3 and 4 of these guidelines explains why a new zonation scheme was established using markers not traditionally exploited by the global zonation schemes of Martini (1971) and Okada and Bukry (1980). The marker species used by these global zonation schemes, if present, tend to have patchy occurrences and very low abundances in all the studied well sections in Iraq.

CHAPTER FIVE
TAXONOMY

5.1 Introduction.

The taxonomy of the marker species used to establish the zonation scheme in this study are described, based upon Farinacci (1969-1979), Farinacci (1971), Haq (1978), Romein (1979), Aubry (1985), Perch-Nielsen *et al.* (1985), Gallagher (1987) and personal observations.(1) A full list of all the species of calcareous nannofossil encountered during this study can be found in Figure 5.8 Tables 1a - 1u and the wells listed are: Atshan No. 1 (At-1), Bai Hassan No. 8 (BH-8), Bai Hassan No. 10 (BH-10), Chemchemal No. 2 (Ch-2), Jambur No. 4 (Ja-4), Kirkuk No. 85 (K-85), Kirkuk No. 116 (K-116), Musaiyib No. 1 (Mu-1), Pulkhana No. 5 (Pu-5) and Rachi No. 1 (Ra-1).

(1) The species are grouped into families which are described below in alphabetical order

5.2 Family: COCCOLITHACEAE Poche 1913 (see Figure 5.1).

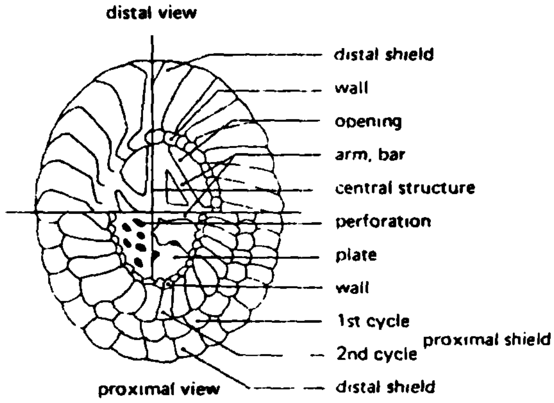


Figure 5.1 Terminology of the Coccolithaceae (after Perch-Nielsen *et al.* 1985).

Description: Elliptical and circular coccoliths with a distal shield made up of radiating petaloid elements. Most of the genera in this family arrange their crystal units within the larger distal shield so that they are non-birefringent where as in the proximal shield they arrange their crystal units so that they are highly birefringent, between crossed polars in the L.M.. This arrangement of crystal units explains why most coccoliths of the Coccolithaceae appear larger in plane polarized light than between crossed polars. Perch-Nielsen *et al.* (1985) divided the Coccolithaceae into three groups based on the outline and the nature of the central area:

5.0 Taxonomy

1. elliptical and circular Coccolithaceae with a distinct central area structure. The genera included in this group are *Bikelundia, Bramletteius, Campylosphaera, Chiasmolithus* and *Cruciplacolithus*;

2. elliptical Coccolithaceae which posses open or closed central area. The genera included in this group are *Birkelundia, Clausicoccus, Coccolithus* and *Ericsonia*;

3. circular Coccolithaceae with an open or closed central area. The genera included in this group are *Calcidiscus* (synonymous with *Cyclococcolithus, Cyclococcolithina, Cycloplacolithella, Cycloplacolithus* and *Tiarolithus*), *Conococcolithus, Coroncyclus, Cyclagelosphaera, Cycloperfolithus, Hayella, Ilselithina, Markalius, Neosphaera, Pedinocyclus, Striatococcolithus* and *Umbilicosphaera.*

*Genus: **Ericsonia*** Black 1964.

Description: *Ericsonia* is subelliptical or circular in plan view and concavo-convex in side view and comprises three cycles:

1. An outer cycle of non-imbricate elements with subradial sutures.
2. A median cycle of elements that imbricate in an anticlockwise manner in which the sutures between the elements are oblique.
3. An inner cycle of elements that imbricate in a clockwise manner in which oblique sutures occur between the elements.

This description of *Ericsonia* was based upon a proximal view of the type species *E. occidentalis*. Romein (1979) deduced from this description that the outer cycle represents the proximal side of the distal shield. He also offered two explanations for the other cycles; one suggesting that the median cycle represents the proximal shield and the inner cycle the proximal side of the rim and one suggesting that the median cycle represents the wider proximal cycle of the distal shield and the inner cycle represents the proximal shield. The later description was favoured by Romein (1979), as other species assigned to *Ericsonia* (*E. alternans* and *E. ovalis*) exhibit four cycles of elements the inner most of which is the proximal side of the wall. If this description holds *Ericsonia* can be differentiated from *Coccolithus* by the presence of a defined proximal cycle in the distal shield, which projects beyond the proximal shield.

Ericsonia is considered by many workers to be a junior synonym of *Coccolithus*. This because the generotypes of both, *Coccolithus pelagicus* and *Ericsonia formosa*, are very similar in proximal views. However, since the erection of *Ericsonia* by Black (1964), many species have been assigned to it mainly from the Paleogene.

Species: ***E. subdisticha*** (Roth & Hay *in* Hay et al., 1967) Roth *in* Baumann & Roth (1969).

Plate No. 1, Figure 5.

Type Locality: Mid-Pacific Ocean, dredged sample MP 25c-1 (Roth & Hay *in* Hay *et al.*, 1967).

Age Range: Late Eocene to Early Oligocene NP19 - NP21/ CP15b - CP16a (Perch-Nielsen *et al.* 1985).

Type Size: 4.3 µm.

Description: *E. subdisticha* has an elliptical distal shield composed of about 30 subtrapezoidal elements, which are dextrally imbricated, and the curvature of the sutures between the elements is slightly laevogyre. The central area posses a longitudinal ridge flanked by four pairs of pores. The ends of the ridge are also delimited by two pores lying in the long axis.

Remarks: *E. subdisticha* can be differentiated from *E. obrupta* Perch-Nielsen (1971c), as *E. obrupta* is generally larger, less elliptical, and has a broader rim.

5.3 Family: **DISCOASTERACEAE** Tan 1927 (see Figure 5.2).

Description: The Discoasteraceae family comprises nannoliths that possess a star or rosette type morphology. In distal view between cross polars the specimens remain dark as the C-axes of the individual calcite crystal units is vertical. In all, the family contains 12 genera all of which were grouped under three genera by Perch-Nielsen *et al.* (1985). These are *Catinaster*, *Discoaster* and *Discoasteroides*. Perch-Nielsen *et al.* (1985), considered *Agalmatoaster*, *Clavodiscoaster*, *Gyrodiscoaster*, *Truncodiscoaster*, *Turbodiscoaster*, *Radiodiscoaster*, *Hemidiscoaster* and *Heliodiscoaster* to be synonymous with *Discoaster*.

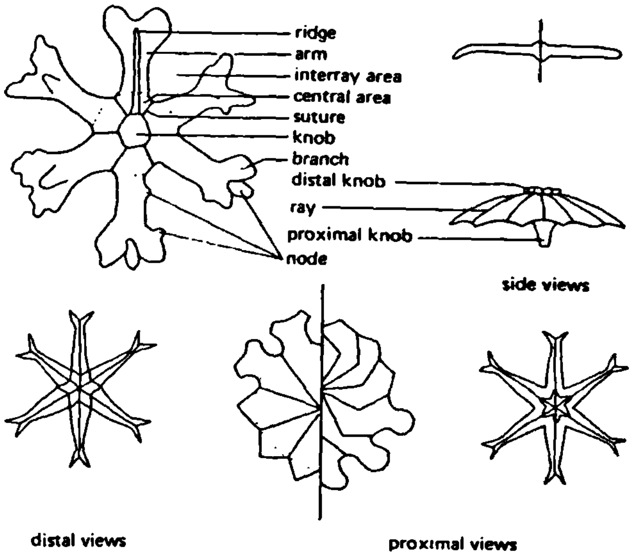


Figure 5.2 Terminology of the Discoasteraceae (after Perch-Nielsen *et al.* 1985).

Genus: ***Discoaster*** Tan 1927.

Description: *Discoaster* is used to describe a nannolith that possess a relatively flat, star or rosette shaped morphology.

D. binodosus Martini 1958.

Type Locality: Golwitz, Northwest Germany.

Age Range: Latest Palaeocene to Mid Eocene NP9 - NP16/ CP8b - CP13b.

Type Size: 8.4 - 16.4 µm.

Description: *D. binodosus* has 6 to 8 rays, rarely 9 rays, which are free for approximately half of there length. The size and shape of the rays is highly variable, they may be long, short parallel-sided or outwardly tapering, with or without terminal bifurcation. The rays possess paired nodes half way between the central area and the ray tip. The central area is relatively large and possess a central flat knob surrounded by a ring of depressions and the notch in the inter-ray area is rounded. The great variability in the rays led Martini (1958) to establish two subspecies *D. binodosus hirundus* and *D. binodosus binodosus*, the later of which occurs in the samples from the study area.

5.0 Taxonomy

Discoaster binodosus binodosus **Martini 1958.**

Plate No. 1, Figures 14a and 14b.

Description: *D. binodosus binodosus* has outwardly tapering rays with rounded tips.

Remarks: Prins (1971) suggests that the central knob appears in the Late Palaeocene forms where as Aubry (1985) suggests the central knob only appears in the earliest Eocene forms. Perch-Nielsen *et al.* (1985), differentiated early forms of *D. binodosus* from *D. mediosus* Bramlette and Sullivan (1961) by the fact that the latter have longer free rays and do not possess the pairs of nodes. Perch-Nielsen *et al.* (1985), also differentiates between *D. binodosus* and *D. limbatus* Bramlette and Sullivan (1961) as the latter has shorter rays and a smaller central area.

D. kuepperi Stradner 1959.

Plate No. 1, Figures 8a and 8b.

Type Location: Mattsee, Saltzburg, Austria (Station 130; selten).

Age Range: Lower Eocene NP12 - NP14/ CP10 - CP12b.

Type Size: 8.0 - 14.0 µm.

Description: *D. kuepperi* comprises 8 to 12 rays, commonly 9 rays which are rounded and joined throughout most of their length. Near the centre of the proximal side the rays extend in proximal and sideward directions to form a funnel-shaped cone, which exhibits dextrogyre sutures in proximal views. The height and width of this cone is highly variable and brightly birefringent in side view when viewed between crossed polars.

Remarks: The highly birefringent cone in *D. kuepperi* enables it to be identified even in heavily calcified specimens.

D. multiradiatus Bramlette & Riedel 1954.

Plate No. 1, Figure 13.

Type Locality: Velasco Shale (Palaeocene or uppermost Cretaceous), 500 metres N 70' W of Estacion Velasco, approximately 75 km. W of Tampico Mexico.

Age Range: NP9 - NP11/ CP8a - CP9b.

Type Size: 9.0 - 15.0 µm.

Description: *D. multiradiatus* is a biconvex rosette-shaped discoaster that comprises 16-35 rays joined throughout their length with a depression along their sutures. Distally the rays are bluntly pointed to produce a serrate margin. The central area of both faces is commonly slightly depressed. The nature of the proximal and distal central area is rather variable in the early stages of development of this species. On the proximal side the sutures between the rays may be straight and continue into the centre, or elements in the centre may be separated by dextrogyre sutures which are bright in crossed polars, or the elements may be enlarged toward the centre forming a short stem. On the distal side the rays in the central area may be slightly imbricate in a clockwise manner near to the depressed centre, alternatively there may be a thin distal cycle of elements separated by radial sutures or two concentric circles which are bright between crossed polars.

Remarks: *D. multiradiatus* is a solution resistant species and Perch-Nielsen *et al.* (1985) also noted that in younger forms the central stem appears and the number of rays decrease from older to younger forms. However, specimens may or may not exhibit a central stem or knob. Bramlette and Riedel (1954) differentiated between *D. multiradiatus* and *D. barbadiensis* Tan (1927) by the fact the latter has fewer rays and being more nearly complanate and thinner in proportion to the diameter. They also differentiated *D. multiradiatus* from *D. perplexus* Bramlette and Riedel (1954) by the fact that *D. multiradiatus* has a greater diameter and a serrate margin. In this study *D. wemmelensis* Achuthan and Stradner (1969) has been identified and it can be differentiated from *D. multiradiatus* as it is smaller, is made up of two cycles of elements and never exhibits a central knob.

5.4 Family: **FASCICULITHACEAE** Hay & Mohler 1967 (see Figure 5.3).

Genus: **Fasciculithus** Bramlette & Sullivan 1961.

Description: Fasciculithus is a compound cylindrical structure that consists of a proximal column, lateral elements or a disc, and a distal cone. In some cases the elements in the proximal column can be in contact with each other to form a central body. Also in some cases the proximal column may exhibit depressions or fenestrae.

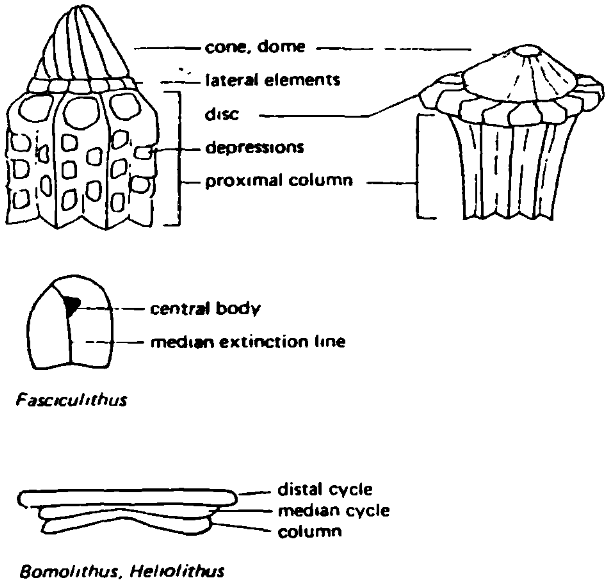


Figure 5.3 Terminology of the Fasciculithaceae and Heliolithaceae (after Perch-Nielsen *et al.* 1985).

Fasciculithus sp. 1

Plate No.6, Figure 21.

Type Locality: Sample Ch-2/ 110, Chemchemal No. 2, Northern Iraq.

Age: Late Paleocene NP9/CP8a-CP8b

Type Size: 7.0 - 8.0 µm.

Description: *Fasciculithus* sp. 1 comprises lateral elements which forms a strongly tapering, high, pointed, proximal column, with convex sides. Towards the apex of the proximal column the species seems to exhibit a single row of fenestrae. The base of the proximal column has a slight depression so it is concave upwards.

Remarks: *Fasciculithus* sp. 1 is synonymous with *Fasciculithus* sp. of Perch-Nielsen *et al.* (1985). *Fasciculithus* sp. 1 can be differentiated from *F. thomasii* Perch-Nielsen (1971b) as the proximal column has convex sides throughout its length and end in a point instead of a low cone. *Fasciculithus* sp. 1 can be differentiated from *F. alanii* Perch-Nielsen (1971b) as the sides are convex and the proximal column terminates forming a higher, more pointed fashion than *F. alanii.*

F. hayi Haq 1971.

Plate No. 1, Figure 17.

Type Locality: West Central Iran.

Age Range: Late Palaeocene NP9/ CP8a - CP8b.

Type Size: About 8.0 µm.

Description: *F. hayi* has a simply constructed proximal column comprising six lateral elements surmounted by a short cone or dome.

Remarks: Aubry (1985) differentiated this species from *F. schaubi* Hay and Mohler (1967) as it has more acute angles at the top in the cone and bottom in the base of the proximal column. Perch-Nielsen *et al.* (1985) suggests that *F. hayi* may be synonymous with *F. lillianne* Perch-Nielsen (1971b) but, the former may be distinguished from the latter by possessing a slightly conical proximal part of the column, instead of the parallel sides in *F. lillianae.*

F. pileatus Bukry 1973.

Plate No. 1, Figure 19.

Type Locality: DSDP Legs in the Pacific, Indian and Atlantic Oceans and the Caribbean Sea.

Age Range: Mid Palaeocene NP4 - NP6/ CP3 - CP5.

Size: 5.0 - 12.0 µm.

Description: *F. pileatus* comprises a truncated cone shaped column with smooth straight walls which expand from the base towards the apex. A large, convex-topped, lens shaped cone or dome covers the entire top of the proximal column and can extend beyond it. A central stud may connect the cap and column in some specimens. In crossed nicols, side views have a straight dark median line bisecting the column and a straight or convex downward towards the base dark line separating the column from the dome, forming three bright areas.

Remarks: Aubry (1985) assigns a long age range to F. pileatus (NP4 - NP9/ CP3 - CP8a). However, Perch-Nielsen et al. (1985) suggests a much more restricted age range (NP4 - NP6/ CP3 - CP5), this age range has been used in this study as *F. pileatus* was never found with any younger sediments in the samples covered in this study.

F. tympaniformis Hay & Mohler in Hay et al. 1967.

Plate No. 1, Figure 16.

Type Location: Exposure along Route Nationale 134bis, about 250 meters northwest of Pont Labau, 3 kilometres south of Gan, Basses Pyrenees, France.

Age Range: NP5 - NP10/ CP4 - CP9a.

Size: 4.0 - 6.0 µm.

Description: *F. tympaniformis* comprises 16 wedge shaped lateral elements in the proximal column which are arranged so that their thin edges meet the centre, and thicker edges meet the outer surface of the proximal column. The outer surface of the proximal column is smooth and lacks any ornamentation and tapers distally to form a low dome or cone.

Remarks: Hay & Mohler *in* Hay *et al.* (1967) distinguish *F. tympaniformis* from *F. involutus* Bramlette and Sullivan (1961) by the latter possessing a smooth outer surface.

5.5 Family: HELIOLITHACEAE Hay & Mohler 1967 (see Figure 5.3).

Description: Heliolithaceae is closely related the Fasciculithaceae and includes two genera *Bomolithus* and *Heliolithus*. *Bomolithus* consists of three cycles of elements and *Heliolithus* of two in *H. riedelii*, the generotype, and of three in *H. kleinpellii*. Romein (1979), included *Bomolithus* in *Heliolithus*, but Perch-Nielsen *et al.* (1985) regarded *Bomolithus* as an early representative of the Heliolithaceae.

Genus: ***Heliolithus*** Bramlette & Sullivan 1961.

Description: As described earlier *H. kleipellii* has three cycles of elements and *H. riedelii*, the generotype has only two cycles. However, all *Heliolithus* appear highly birefringent between crossed polars unlike the other genus in this family, *Bomolithus*.

Species: ***H. kleinpellii*** Sullivan 1964.

Plate No. 1, Figure 18.

Type Locality: Martinez Beds, Simi Valley Area, Ventura County, California.

Age Range: Mid - Late Palaeocene NP6 - NP9 / CP5 - CP8a.

Type Size: 10.0 - 17.0 µm.

Description: *H. kleinpellii* is a rather large, flat form which is highly birefringent in nature. However, the column and median cycles appear even more highly birefringent than the much larger distal cycle, and are about two thirds the diameter of the distal cycle. Each cycle consists of about 45 radiating blade-like elements. The central area can be occupied by radially or tangentially arranged elements of the column and the median cycle or it may be open. The extinction cross is straight and thin in the central area of the heliolith but becomes curved and flaring over most of the heliolith, thus covering about half of each quadrant.

Remarks: *H. kleinpelli* is usually the largest nannofossil in the samples it occurs in. Sullivan (1964), differentiated *H. klienpelli* from *H. riedelii* Bramlette and Sullivan (1961) in being larger, more oppressed, and having a greater number of radiating elements.

5.6 Family: **Noelaerhabdaceae Jerkovič 1970** (see Figure 5.4).

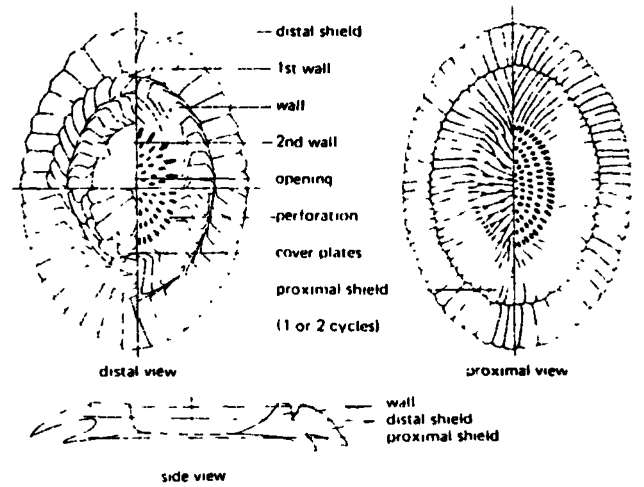


Figure 5.4 Terminology of the Noelaerhabdaceae (after Perch-Nielsen *et al.* 1985).

Description: The Noelaerhabdaceae family comprises elliptical and circular placoliths which are concavo-convex in side view. The proximal and distal shields of placoliths in this family are bright between crossed polars and they exhibit strong extinction lines. This strong birefringence means that the placoliths of this family appear as large as they do between crossed polars. Gallagher (1987), noted in his work on Noelaerhabdaceae that the genus *Cyclicargolithus* is taxonomically significant as it possesses no central area structures. However he suggests that the genus *Dictyococcites* is synonymous with *Reticulofenestra*, as the only difference in structure involves changes in central area, which is considered to be significant only on a specific level. These views have been used as a basis for this study. The family Noelaerhabdaceae contains *Cyclicargolithus, Reticulofenestra, Prinsius and Toweius.*

Genus: ***Cyclicargolithus*** Bukry 1971a.

Description: Cyclicargolithus is a circular to subcircular form which is concavo-convex in side view and possesses a small central opening.

Species: *C.* ***abisectus*** (Müller, 1970) Wise 1973.

Plate No. 1, Figure 1.

Type Locality: DSDP Leg No. 18, North Pacific Ocean.

Age Range: Late Oligocene to Early Miocene, NP24 - NN1/ CP19a - CN1a.

Type Size: 8.8 - 10.6 μm.

Description: The placolith has a circular or slightly elliptical outline. The distal and proximal shield of the placolith is made up of 50 to 55 elements. In distal view the elements show a dextral imbrication. The sutures between these elements exhibit a slight clockwise inclination in distal views, but are straight in proximal views. The tube cycle is cylindrical and joins the proximal shield and has no prominent protrusions so that the central area is open.

Remarks: *C. abisectus* differs from *C. floridanus* Bukry (1971a) by possessing more elements within its distal and proximal shields, and by the fact that the central area is open, with no prominent protrusions from the tube cycle.

Genus: ***Reticulofenestra*** (Hay, Mohler & Wade, 1966) emend. Gallagher 1987.

Description: *Reticulofenestra* comprises elliptical and circular placoliths which are concavo-convex in side view and contain central area grills with variable geometries, as well as a central area tube cycle. The proximal shield is made up of a number of radiating, slightly imbricated elements which extend proximally in various combinations to form central area structures. These elements also project distally to form a tube cycle which lines the margin of the proximal cycle and abuts the distal shield. The distal shield comprises wedge-shaped elements that are imbricated and separated by sharply kinked structures adjacent to the tube cycle. The tube cycle may project inward to give the central area a completely close appearance.

Species: ***R. bisecta*** (Hay, Mohler & Wade, 1966) Roth 1970.

Plate No. 1, Figures 2a and 2b.

Type Locality: Nal'chik, Nal 11, Commonwealth of Independent States (C.I.S.).

Age Range: Mid Eocene to Late Oligocene NP15 - NP25/ CP13a - CP19b.

Type Size: 8.0 - 11.0 μm.

Description: *R. bisecta* is typically bright between crossed polars and in distal views comprises 66 wedge-shaped dextrally imbricated elements. The sutures between the elements also exhibit a slight clockwise inclination. The smaller proximal shield also comprises 66 wedge-shaped elements but they are non-imbricate and the sutures between the elements are straight. The central area on the distal side, is generally totally covered by plates, except for a slit like hole which extends almost across the entire central area. This is a distinctive feature and shows up particularly well in crossed polars as a straight dark line bisecting the central area of the placolith. Gallagher (1987) described a central grill that occurs underneath these plates based on electron micrographs. He suggests this grill was constructed from every third shield element projecting towards the centre of the placolith. The tube cycle is made up of multiple cycles of imbricated tabular elements.

Remarks: *R. bisecta* can be distinguished from *R. scrippsae* Roth (1973) as the latter is smaller and exhibits sharply kinked extinction lines across its central area between crossed polars.

Species: ***R. callida*** **(Perch-Nielsen, 1971d) Bybell 1975.**

Plate No. 1, Figure 7.

Type Locality: Orby, Denmark.

Age Range: Mid Eocene NP14 - NP15/ CP13a - CP13b.

Type Size: 7.0 µm.

Description: *R. callida* is slightly elliptical or rounded in outline and the distal shield comprises 50 to 70 wedge-shaped elements that terminate distally in a point. The sutures between theses elements on the distal shield are sharply kinked in a clockwise fashion adjacent to the tube cycle. The proximal shield is only slightly smaller than the distal shield and is made up of the same number of elements. The central area of this placolith is made up of radiating rods formed by every second element of the tube cycle projecting towards the centre. These rods meet in the centre of the placolith to form a prominent knob structure. This central area structure appears as a distinctive cross between crossed polars.

Remarks: *R. callida* can be distinguished from *R. reticulata* Roth and Theirstein (1972) as the distinctive cross type structure that is visible in the central area between crossed polars is made up of more bulbous bars in *R. callida* than in *R. recticulata*. Perch-Nielsen (1971d) noted a more restricted Mid Eocene (NP14 - NP15/ CP13a - CP13b) age range for *R. callida* than Gallagher (1987) who noted a Early Eocene to Mid Oligocene (NP13 - NP23/ CP11 - CP18) age range. The more restricted age range of Perch-Nielsen (1971d) has been used in this study as the first down hole occurrence of *R. callida* in all studied sections occurs below the first down occurrence of *R. dictyoda*.

Species: ***R. dictyoda*** **(Deflandre & Fert, 1954) Stradner in Stradner & Edwards 1968.**

Plate No. 1, Figures 6a and 6b.

Type Locality: Donzacq, France.

Age Range: Early to Mid Eocene NP13 - NP16/ CP11 - CP14a.

Type Size: 4.0 - 10.0 µm.

Description: In *R. dictyoda* the distal shield is 25 - 30% larger than the proximal shield and both are composed of 40 - 60 wedge-shaped elements. The central area is small and makes up to 25% of the total placolith area. The central area contains a grill made up of rods derived from every second proximal shield element, which delinate long holes towards the margin of the central area and irregular holes towards the centre of the central area.

Remarks: *R. dictyoda* can differentiated from *R. umbilica* Martini and Ritzkowski (1968) as the former is smaller and has its first and last appearance below the latter.

5.7 Family: POLYCYCLOLITHACEAE Forchheimer 1972.

Desciption: The Polycyclolithaceae comprises mainly cylindrical, block, star or rosette-shaped extinct nannoliths with or without obvious evolutionary links. This family is synonymous with Lithastrinaceae and Eprolithaceae and includes the following genera; *Eprolithus, Lithastrinus, Micula, Polycyclolithus, Quadrum* and *Radiolithus* which have obvious evolutionary relationships. This family also includes *Assipetra, Hayesites, Hexalithus, Pervilithus, Polycostella* and *Rucinolithus* which have questionable evolutionary relationships.

Genus: *Micula* Vekshina 1959.

Description: Micula comprises interlocking calcite units in the shape of a cube.

Species: *M. murus* (Martini, 1961) Bukry 1973.

Plate No. 1, Figure 20.

Type Locality: DSDP Leg 15, Caribbean Sea.

Age Range: Late Maastrichtian CC25c - CC26.

Type Size: 5.9 - 6.0 µm.

Description: *M. murus* comprises interlocking calcite units forming a cube-shape morphology with projecting rays. The sutures between the units are strongly bent forming a swastika type pattern. The central area is depressed and is more or less funnel-shaped.

Remarks: *M. murus* can be differentiated from *M. praemurus* Stradner and Steinmetz (1984) as the rays project more and the sutures are more strongly bent in *M. murus*. *M. murus* can be differentiated from M. prinsii Perch-Nielsen (1979a) as the rays are thicker and shorter than *M. prinsii. M. murus* is rare or absent in high latitudes, but has proven to be useful in marking the top of the Late Mastrichtian in mid and low latitudes.

5.8 Family: SPHENOLITHACEAE Deflandre 1952 (see Figure 5.5).

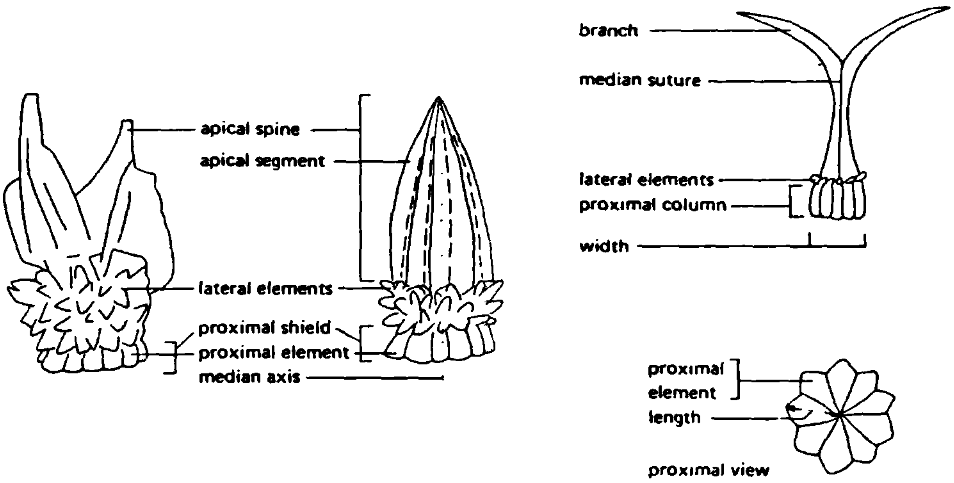


Figure 5.5 Terminology of the Sphenolithaceae (after Perch-Nielsen *et al.* 1985).

Description: This family only contains the genus *Sphenolithus* and does not contain any of the additional genera described by Tappan (1980). Bramlette and Wilcoxon (1967) also included the monospecific genera *Furcatolithus* and *Nannoturbella* within *Sphenolithus*. The holotype is *Sphenaster metula* Wilcoxon (1970b) which has now been shown to be a proximal shield of a sphenolith.

Genus: ***Sphenolithus*** Deflandre 1952.

Description: *Sphenolithus* are nannoliths comprising a proximal shield or column, one or several layers of lateral elements and an apical or distal structure which is commonly elongated and may show bifurcation. Several species of this genus are useful stratigraphic markers and are readily identified in the light microscope between cross polars, between 0° and 45° to the polarizer.

5.0 Taxonomy

Species: *S. conspicuus* Martini 1976.

Plate No. 1, Figures 9a and 9b.

Type Locality: Manihiki Plateau, Central Pacific Ocean.

Age Range: Early Eocene NP11 - NP12/ CP9b - CP10.

Type Size: 5.0 - 10.0 μm.

Description: *S. conspicuus* comprises approximately 12 regularly placed proximal elements in the proximal shield and some irregularly placed lateral elements arranged, in what may be mistaken as rows, from these lateral elements a prominent apical spine emerges. This apical spine is not visible when viewed at 0° between crossed polars but is very conspicuous, massive and highly birefringent when viewed at 45° between crossed polars.

Remarks: Perch-Nielsen *et al.* (1985), and Aubry (1985) both differentiate *S. conspicuus* from *S. anarrhopus* Bukry and Bramlette (1969a), as the former has a symmetrical and the latter an asymmetrical bent apical spine when viewed at 45° between crossed polars. Aubry (1985) also differentiates *S. conspicuus* from *S. delphix* as the extinction cross in the base of the sphenolith is symmetrical in the former and asymmetrical in the form of a crucifix in the latter.

Species: *S. distentus* (Martini, 1965) Bramlette & Wilcoxon 1967.

Plate No. 1 Figure 3a and 3b.

Type Locality: Pacific deep sea core MP 40-1 (15° 13'N, 177° 32'W; water depth 4082m), at 56-63 cm; Miocene (approximately equivalent to Catapsidrax dissimilis Zone, Cipero Formation, Trinidad).

Age Range: Late Oligocene NP23 - NP24/ CP18 - CP19a.

Type Size: 9.0 - 13.0 μm.

Description: *S. distentus* comprises 12 - 14 proximal elements in the proximal shield and some lateral elements which may or may not be present. An apical spine arises from the proximal shield and is made up of two elongate elements that tapper distally and meet along the median axis. The distal end of the apical spine normally bifurcates forming two long thinner spines which diverge at an angle of about 90°. The main body of the sphenolith and these spines lie in the same plane.

Remarks: Perch-Nielsen *et al.* (1985) differentiates *S. distentus* from *S. predistentus* Bramlette and Wilcoxon (1967) as the former has an almost straight extinction line between the proximal column and the apical spine when viewed at 45° to cross polars and the latter has a V-shaped extinction line. S. distentus is synonymous with *Furcatolithus distentus* of Martini (1965). Bramlette and Wilcoxon (1967), suggested that *S. distentus* is evolved from *S. predistentus* as the name implies.

Species: *S. moriformis* Group.

Description: This is used in this study to group those sphenoliths that lack prominent apical spines and are dissected by two extinction lines at 90° to each other which remain in this configuration even when rotated.

Age Range: Palaeocene to Early Miocene in this study.

Remarks: *S. moriformis* Group can be differentiated from *S. moriformis* Bramlette and Wilcoxon (1967) as the former does not change its extinction pattern when rotated.

Species: *S. predistentus* (Martini, 1965) Bramlette & Wilcoxon 1967.

Plate No. 1, Figures 4a to 4c.

Type Locality: Between the Globigerina ampliaperta and Globorotalia opima opima zones of the Cipero Formation section, Trinidad.

Age Range: Mid Eocene to Late Oligocene NP14 - NP23/ CP12b - CP18.

Type Size: 9.0 - 13.0 µm.

Description: *S. predistentus* comprises 10 - 12 proximal elements in the proximal shield with no lateral elements. The apical spine comprises two elongate elements that taper distally and meet along the median axis. The gross morphology of the apical spine, is conical with a broad base. The apical spine appears bright with a median suture at 0° to the cross polars and bright without a median suture at 45° to the crossed polars. The distal tip of the apical spine may also exhibit slight bifurcation.

Remarks: Perch-Nielsen *et al.* (1985) differentiates *S. predistentus* from *S. distentus* in that the former, when viewed at 45° to crossed polars, has a straight extinction line at the base of the apical spine whilst the latter, as described above, has a V-shaped extinction line at the base of the apical spine.

5.9 INCERTAE SEDIS

Genus: ***Rhomboaster*** Bramlette & Sullivan 1961.

Description: *Rhomboaster* includes those nannofossils which are constructed of a single calcite unit which has a rhombohedral form with depressed faces. Speciation of Rhomboaster is determined by the outline of its calcite block. In crossed polars *Rhomboaster* exhibits low birefringence. Similar forms occur in the Late Cretaceous, *Micula*, and in fact Romein (1979) coded *Rhomboaster* in a similar way as Micula when he produced diagrams to explain the taxonomy. For the standard orientation in plane view the 1-3 diagonal is placed parallel to the Y-crosshair. Similar forms to *Rhomboaster* are also present in the Mid Eocene (*Nannotetrina*), however *Rhomboaster* species range only from the Latest Palaeocene to the Earliest Eocene.

Species: ***R. bitrifida*** Romein 1979.

Plate No. 1, Figure 15.

Type Locality: Jorquera Formation, Member D. Barranco del Gredero, South East Spain.

Age Range: Uppermost Late Palaeocene to Lowermost Early Eocene NP9 - NP10/ CP8b - CP9a.

Type Size: 6.0 - 10.0 µm.

Description: *R. bitrifida* form is that of a high rhombohedron with strongly depressed faces, so that cuspate corners are formed. Four arms are visible in the upper face: three longer ones, pointing in the direction of the corners 1, 2 and 4, and a shorter one pointing in the direction of corner 3. The configuration in the lower face is the mirror image of the upper face.

Remarks: Romein (1979), noted that in early forms of *R. bitrifida* the arms 1a and 3 are somewhat more pronounced than in later specimens, this description is reminiscent of the specimens of this species of *Rhomboaster* recorded in this study. Romein (1979), differentiated *R. bitrifida* from *R. calcitrapa* by the fact that in former the arms are shorter.

5.0 Taxonomy

Genus: ***Tribrachiatus*** (Bramlette & Riedel, 1954) Shamrai 1963.

Description: *Tribrachiatus* is an Eocene nannolith composed of a single calcite unit which has a triradiate structure. However, Romein (1979), emended this description to include hexaradiate forms. Similar Cretaceous forms are assigned to *Marthasterites*, and similar Miocene and Pliocene forms are included under *Discoaster*. These three forms are not thought to be related. However, Romein (1979) suggests that this genus evolved from *Rhomboaster* around the Palaeocene/ Eocene boundary and also notes the full evolutionary trend from *T.nunnii* to *T. orthostylus* within *Tribrachiatus*. This evolutionary trend is illustrated in Figure 5.6, with some extra details and a list of published photomicrographs on each stage of the evolution.

Species: *T. contortus* (Stradner, 1958) Bukry, 1972.

Plate No. 1, Figure 12.

Type Locality: Described from a reworked occurrence in Miocene sediments from Austria.

Age Range: Early Eocene NP10/ CP9a.

Type Size: 11 - 15 µm.

Description: *T. contortus* has six arms of which three on each side are connected in a similar way to *T. orthostylus* Shamrai (1963) described below. The angle of contortion between the pair of ray groups is variable and was used by Perch-Nielsen *et al.* (1985) to establish three types:

T. contortus Type A: The angle between the ray groups is less than or equal to 90°.

T. contortus Type B: The angle between the ray groups is greater than 90°.

T. contortus Type C: The two layers are still recognisable, but they nearly overlap each other.

Remarks: The last occurrence of *T. contortus* marks the top of NP10/ CP9a and is used in this study to mark the boundary between NP10/ CP9a and NP11/ CP9b. *T. contortus* evolved from *T. nunnii* at the base of NP10/ CP9a and evolved into *T. orthostylus* at the boundary between NP10/ CP9a and NP11/ CP9b. This latter evolutionary event was noted in this study in the I.P.C. Well Chemchemal No. 2 and

is illustrated in Figure 5.7.

Species: *T. orthostylus* (Bramlette & Riedel) Shamrai (1963).

Plate No. 1, Figures 10 and 11.

Type Locality: Lodo Formation, California, U.S.A.

Age Range: Early Eocene NP10 - NP14/ CP9a - CP12b.

Size: 8.0 - 13.0 μm.

Description: *T. orthostylus* is a triradiate nannolith comprising three, sub-cylindrical, commonly slightly tapering rays which can be either bluntly truncated or posses a small or large terminal notch. The rays are generally bent.

Remarks: Perch-Nielsen *et al.*, (1985), split *T. orthostylus* into two types:

***T. orthostylus* Type A:** The rays posses terminal notches.

Age Range: Early Eocene NP10 - NP11 / CP9a - CP9b.

***T. orthostylus* Type B** The rays have no terminal notches.

Age Range: Early Eocene NP10 - NP14 / CP9a - CP12b.

The two types of *T. orthostylus* can be seen in Plate No. 1, Figures 10 and 11, and the evolution between these two types was also noted in this study again in the I.P.C. Well Chemchemal No. 2 and is illustrated in Figure 5.7. Hay *et. al.* (1967), suggested that *T. orthostylus* evolved from *T. contortus*.

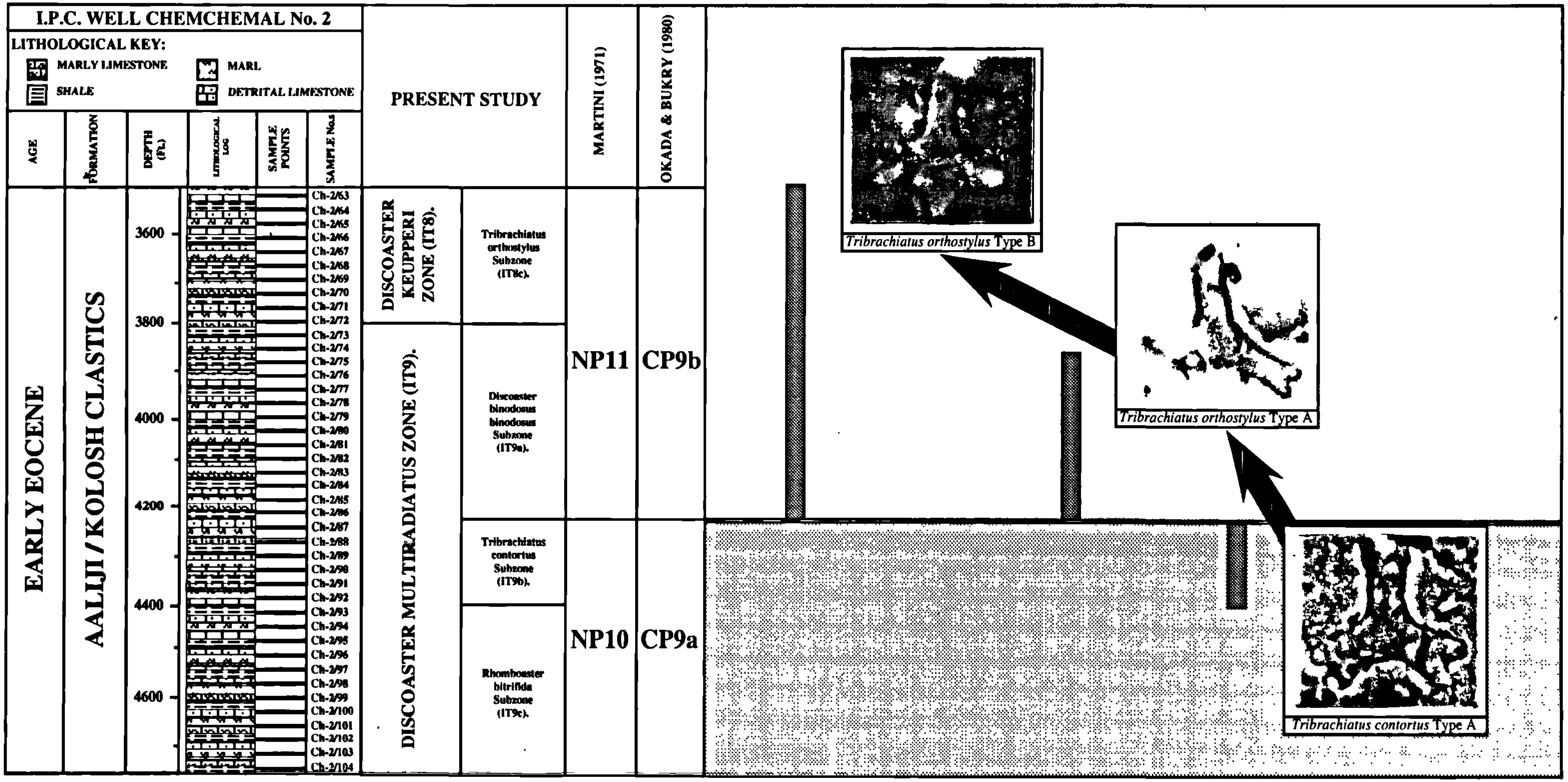


Figure 5.7 Evolution within the genus *Tribrachiatus* noted in the I.P.C. Well Chemchemal No.2.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Arkhangelskiella cymbiformis	Vekshina, 1959.	Mid Campanian - Late Maastrichtian. CC20 - CC26.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Aspidolithus parca parca	(Stradner, 1963) Noël, 1969.	Early to Mid Campanian. CC18 - CC19a.	Pu-5.	Aaliji.
Braarudosphaera bigelowii	(Gran & Braarud, 1935) Deflandre, 1957.	Late Cenomanian - Late Eocene. CC10 - NP20 / CC10 - CP15b.	BH-8, Mu-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Serikagni, Tarjil, Palani, Sinjar Lm., Jaddala, Rus Anhydrite, Kolosh Clastics and Aaliji.
Birkelundia staurion	(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971c.	Mid Eocene. NP15 - NP16 / CP13c - CP14a.	Ra-1.	Rus Anhydrite.
Calculites ovalis	(Stradner, 1963) Prins & Sissingh in Sissingh, 1977.	Late Coniacian - Mid Campanian. CC14 - CC19b.	Pu-5.	Aaliji.
Calcidiscus leptoporus	(Murray & Backman, 1898) Loeblich & Tappan, 1978.	Early Miocene. NN2 - Recent / CN2 - Recent.	Ja-4 and BH-8.	Lower Fars (Transition Beds) and Euphrates Lm.
Calcidiscus macintyrei	(Bukry & Bramlette, 1969b) Loeblich & Tappan, 1978.	Early / Mid Miocene - Early Pliocene. NN4 - NN19 / CN3 - CN13b.	BH-10 and Ra-1.	Ibrahim and Abu Ghar.
Campylosphaera eodela	Bukry & Percival, 1971.	Late Palaeocene - Early Eocene. NP9 - NP10 / CP8b - CP9a.	Ja-4, Mu-1, K-85, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Palani, Sinjar Lm., Jaddala, Kolosh Clastics and Aaliji.
Ceratolithoides kamptneri	Bramlette & Martini, 1964.	Maastrichtian. CC26.	Ch-2 and Pu-5.	Shiranish and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1a.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Chiasmolithus bidens	(Bramlette & Sullivan, 1961) Hay & Mohler, 1967.	Mid Palaeocene - Early Eocene. NP4 - NP11 / CP4 - CP9b.	At-1, Ch-2, Pu-5 and K-116.	Avanah Lm./ Jaddala, Jaddala, Kolosh Clastics, Aaliji and Shiranish.
Chiasmolithus consuetus	(Bramlette & Sullivan, 1961) Hay & Mohler, 1967.	Mid Palaeocene - Late Eocene. NP5 - NP19 / CP4 - CP15b.	Ra-1, Ch-2, Pu-5 and K-116.	Sinjar Lm., Dammam Lm., Dammam Lm./ Rus Anhydrite Boundary, Jaddala/ Aaliji Boundary, Kolosh Clastics and Aaliji.
Chiasmolithus grandis	(Bramlette & Riedel, 1954) Radomski, 1968.	Early Eocene - Mid / Late Eocene. NP11 - NP17 / CP9a - CP14b.	Ra-1, Ja-4 and Pu-5.	Abu Ghar, Jaddala and Rus Anhydite.
Chiasmolithus solitus	(Bramlette & Sullivan, 1961) Locker, 1968.	Early Eocene - Mid Eocene. NP10 - NP16 / CP9a - CP14a.	Ra-1.	Rus Anhydrite.
Chiasmolithus titus	Gartner, 1970.	Mid Eocene - Early Oligocene. NP15 - NP21 / CP13a - CP16a.	Mu-1.	Palani.
Chiastozygus amphipons	(Bramlette & Martini, 1964) Gartner, 1968.	Late Maastrichtian. CC26.	Pu-5 and K-116.	Shiranish.
Chiastozygus litterarius	(Gorka, 1957) Manivit, 1971.	Late Maastrichtian. CC26.	Ra-1, Ch-2, Pu-5 and K-116.	Abu Ghar, Aaliji/ Kolosh Clastics and Shiranish.

Figure 5.8 Taxonomy Table 1b.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Coccolithus pelagicus	(Wallich, 1877) Schiller, 1930.	Palaeocene - Recent.	Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds & Basal Conglomerate), Abu Ghar, Dhiban Anhydrite, Serikagni, Euphrates Lm., Anah Lm., Ibrahim, Bajawan Lm., Baba Lm., Tarjil, Shiek Alas Lm., Palani, Pila Spi Lm., Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Sinjar Lm., Khurmala Lm./ Aaliji, Kolosh Clastics, Aaliji, Umm Er Radhuma, Shiranish and Tayarat Lm.
Cribrosphaerella daniae	Perch-Nielsen, 1973.	Maastrichtian. CC26.	Pu-5.	Aaliji.
Cribrosphaerella ehrenbergi	(Arkhangelski, 1912) Deflandre & Piveteau, 1952.	Late Aptian / Early Albian - Maastrichtian. CC7b - CC26.	Ja-4, Ch-2 and Pu-5.	Lower Fars (Transition Beds), Sinjar Lm., Kolosh Clastics, Aaliji and Shiranish.
Cruciplacolithus latipons	Romein, 1979.	Mid - Late Palaeocene. NP4 - NP9 / CP3 - CP8b.	Ch-2 and Pu-5.	Jaddala, Aaliji/ Kolosh Clastics and Aaliji.
Cruciplacolithus tenuis	(Stradner, 1961) Hay & Mohler in Hay *et al.*, 1967.	Early - Late Palaeocene. NP2 - NP9 / CP1b - CP8b.	Ch-2, Pu-5 and K-116.	Lower Fars (Basal Conglomerate), Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji and Shiranish.

Figure 5.8 Taxonomy Table 1c.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Cyclicargolithus abisectus	(Müller, 1970) Wise, 1973.	Late Oligocene - Early Miocene. NP24 - NN1 / CP19a - CN1a.	Ja-4, BH-10, BH-8, Ra-1, Ch-2 and Pu-5.	Lower Fars (Transition Beds & Basal Conglomerate), Abu Ghar, Euphrates Lm., Serikagni, Anah Lm., Ibrahim, Pila Spi Lm. and Sinjar Lm.
Cyclicargolithus floridanus	(Roth & Hay in Hay *et al.*, 1967) Bukry, 1971a.	Mid Eocene - Mid Miocene. NP14 - NN6 / CP12a - CN5a.	Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Ch-2 and Pu-5.	Lower Fars (Transition Beds & Basal Conglomerate), Abu Ghar, Euphrates Lm., Dhiban Anhydrite, Serikagni, Anah Lm., Ibrahim, Baba Lm., Tarjil, Shiek Alas Lm., Palani, Pila Spi Lm., Avanah Lm./ Jaddala, Jaddala, Khurmala Lm./ Aaliji, Kolosh Clastics/ Aaliji and Aaliji.
Discoaster cf. *D. stella*	Noël, 1961.	Early Eocene. NP10 - NP13 / CP9a - CP11.	Ch-2.	Kolosh Clastics/ Aaliji.
Discoaster adamanteus	Bramlette & Wilcoxon, 1967.	Mid Oligocene - Early Miocene. NP23 - NN3 / CP18 - CN2.	BH-10.	Ibrahim
Discoaster barbadiensis	Tan, 1927.	Early - Late Eocene. NP10 - NP20 / CP9a - CP15b.	Ja-4, BH-8, At-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Baba Lm.alani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Kolosh Clastics, Khurmala Lm./ Aaliji and Aaliji.

Figure 5.8 Taxonomy Table 1d.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Discoaster binodosus binodosus	Martini, 1958.	Late Palaeocene - Mid Eocene. NP9 - NP16 / CP8b - CP13b.	Ch-2.	Kolosh Clastics/ Aaliji.
Discoaster deflandrei	Bramlette & Riedel, 1954.	Early Eocene - Mid Miocene. NP11 - NN7 / CP9b - CN5b.	Ja-4, BH-10, BH-8, K-85, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Euphrates Lm., Serikagni, Ibrahim, Jaddala, Pila Spi Lm., Kolosh Clastics and Aaliji.
Discoaster diastypus	Bramlette & Sullivan, 1961.	Early Eocene. NP10 - NP12 / CP9a - CP10.	Ch-2.	Kolosh Clastics/ Aaliji.
Discoaster druggii	Bramlette & Wilcoxon, 1967.	Early - Mid Miocene. NN2 - NN5 / CN1c - NN4.	Ja-4.	Lower Fars (Transition Beds).
Discoaster falcatus	Bramlette & Sullivan, 1961.	Late Palaeocene - Early Eocene. NP8 - NP10 / CP7 - CP9a.	Ch-2.	Kolosh Clastics/ Aaliji.
Discoaster gemmeus	Stradner, 1959.	Mid Eocene. NP15 - NP16 / CP13a - CP14b.	Ra-1.	Dammam Lm.
Discoaster kuepperi	Stradner, 1959.	Early - Mid Eocene. NP12 - NP14 / CP10 - CP12b.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Jaddala/ Aaliji Boundary, Kolosh Clastics and Aaliji.
Discoaster lodoensis	Bramlette & Riedel, 1954.	Early - Mid Eocene. NP10 - NP14 / CP9a - CP12a.	Ch-2, Pu-5 and K-116.	Kolosh Clastics and Aaliji.
Discoaster mahmoudii	Perch-Nielsen 1981.	Palaeocene. NP9 / CP8b.	Ch-2 and Pu-5.	Kolosh Clastics/ Aaliji and Aaliji.
Discoaster mohleri	Bukry & Percival, 1971.	Mid - Late Palaeocene. NP7 - NP9 / CP6 - CP8b.	Ch-2, Pu-5 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Discoaster multiradiatus	Bramlette & Riedel, 1954.	Late Palaeocene - Early Eocene. NP9 - NP11 / CP8a - CP9b.	Ch-2 and K-116.	Kolosh Clastics, Aaliji and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1e.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Discoaster nobilis	Martini, 1961.	Late Palaeocene. NP8 - NP9 / CP7 - CP8b.	K-116.	Kolosh Clastics and Aaliji.
Discoaster saipanensis	Bramlette & Riedel, 1954.	Mid - Late Eocene. NP15 - NP20 / CP13a - CP15b.	K-85, Ch-2 and Pu-5.	Pila Spi Lm., Jaddala and Aaliji.
Discoaster salisburgensis	Stradner, 1961.	Late Palaeocene - Early Eocene. NP9 - NP12 / CP8b - CP10.	Ch-2 and K-116.	Kolosh Clastics and Kolosh Clastics/ Aaliji.
Discoaster tanii	Bramlette & Riedel, 1954.	Mid Eocene - Late Oligocene. NP17 - NP25 / CP14b - CP17.	Mu-1, K-85 and Pu-5.	Palani, Jaddala and Aaliji.
Discoaster tanii nodifer	Bramlette & Riedel, 1954.	Mid Eocene - Mid Oligocene. NP15 - NP23 / CP13a - CP17.	BH-10 and Pu-5.	Lower Fars (Transition Beds), Ibrahim and Jaddala.
Discoaster variabilis	Martini & Bramlette, 1963.	Early Miocene - Mid Pliocene. NN4 - NN16 / CN3 - CN12a.	At-1.	Avanah Lm./ Jaddala.
Discoaster wemmelensis	Achuthan & Stradner, 1969.	Mid Eocene. NP14 - NP16 / CP12b - CP14a.	Ra-1.	Dammam Lm. and Rus Anhydrite.
Eiffellithus eximius	(Stover, 1966) Perch-Nielsen, 1968.	Late Turonion - Late Campanian. CC12 - CC22b.	Ch-2 and Pu-5.	Kolosh Clastics/ Aaliji and Aaliji.
Eiffellithus gorkae	Reinhardt, 1965.	Mid Santonion - Late Maastrichtian. CC15 - CC26.	Ch-2, Pu-5 and K-116.	Kolosh Clastics/ Aaliji, Aaliji and Shiranish.
Eiffellithus turriseiffelii	(Deflandre in Deflandre & Fert, 1954) Reinhardt, 1965.	Late Albian / Early Cenomanian - Late Maastrichtian. CC9 - CC26.	Ch-2, Pu-5 and K-116.	Kolosh Clastics, Kolosh Clastics/ Aaliji and Shiranish.
Ellipsolithus distichus	(Bramlette & Sullivan, 1961) Sullivan, 1964.	Mid - Late Palaeocene. NP4 - NP9 / CP3 - CP8b.	Ch-2, Pu-5 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.

Figure 5.8 Taxonomy Table 1f.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Ellipsolithus macellus	(Bramlette & Sullivan, 1961) Sullivan, 1964.	Mid Palaeocene - Early Eocene. NP4 - NP12 / CP3 - CP10.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji and Tanjero Clastics.
Ericsonia formosa	(Kamptner, 1963) Haq, 1971.	Early Eocene - Early Oligocene. NP12 - NP21 / CP10 - CP16b.	Ja-4, BH-10, Mu-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Anah Lm., Ibrahim, Palani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Sinjar Lm., Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji and Tanjero Clastics.
Ericsonia obrupta	Perch-Nielsen, 1971c.	Mid Eocene - Early Miocene.	Ja-4, BH-8, K-85, At-1, Ra-1, Ch-2 and Pu-5.	Lower Fars (Transition Beds), Tarjil, Palani, Pila Spi Lm., Avanah Lm./ Jaddala, Dammam Lm., Rus Anhydrite and Aaliji.
Ericsonia robusta	(Bramlette & Sullivan, 1961) Perch-Nielsen, 1977.	Mid Palaeocene - Early Eocene.	BH-10, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Ibrahim, Sinjar Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.
Ericsonia subdisticha	(Roth & Hay in Hay *et al.*, 1967) Roth in Baumann & Roth, 1969.	Late Eocene - Early Oligocene. NP20 - NP21 / CP15b - CP16b.	Ja-4, BH-10, BH-8, Mu-1, K-85 and Pu-5.	Lower Fars (Transition Beds), Serikagni, Baba Lm., Ibrahim, Palani and Jaddala.
Fasciculithus sp. 1	Present Study.	Late Palaeocene.	Ch-2.	Kolosh Clastics/ Aaliji.
Fasciculithus alanii	Perch-Nielsen, 1971a.	Late Palaeocene. NP9 / CP8a - CP8b.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.

Figure 5.8 Taxonomy Table 1g.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Fasciculithus bitectus	Romein, 1979.	Mid Palaeocene. NP4 - NP5 / CP3 - CP4.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Fasciculithus bobii	Perch-Nielsen, 1971a.	Late Palaeocene. NP8 - NP9 / CP7 - CP8a.	Ch-2.	Kolosh Clastics/ Aaliji.
Fasciculithus hayi	Haq, 1971.	Late Palaeocene. NP9 / CP8a - CP8b.	Ch-2 and K-116	Kolosh Clastics/ Aaliji, Aaliji and Tanjero Clastics.
Fasciculithus involutus	Bramlette & Sullivan, 1961.	Late Palaeocene - Early Eocene. NP9 - NP10 / CP8b - CP9a.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Fasciculithus janii	Perch-Nielsen, 1971a.	Mid Palaeocene. NP4 - NP5 / CP3 - CP4.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Fasciculithus pileatus	Bukry, 1973d.	Mid Palaeocene. NP4 - NP6 / CP3 - CP5.	Pu-5 and K-116.	Aaliji.
Fasciculithus richardii	Perch-Nielsen, 1971a.	Late Palaeocene. NP9 / CP8a - CP8b.	Ch-2.	Kolosh Clastics/ Aaliji.
Fasciculithus schaubii	Hay & Mohler, 1967.	Late Palaeocene. NP9 / CP8a - CP8b.	Ch-2 and Pu-5.	Kolosh Clastics/ Aaliji and Aaliji.
Fasciculithus thomasii	Perch-Nielsen, 1971a.	Late Palaeocene - Early Eocene. NP9 - NP10 / CP8a - CP9a.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Fasciculithus tympaniformis	Hay & Mohler in Hay *et al.*, 1967.	Mid - Late Palaeocene. NP5 - NP9 / CP4 - CP8b.	Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Kolosh Clastics, Aaliji, Shiranish and Tanjero Clastics.
Fasciculithus ulii	Perch-Nielsen, 1971a.	Mid Palaeocene. NP4 - NP5 / CP3 - CP4.	Ch-2.	Kolosh Clastics/ Aaliji.

Figure 5.8 Taxonomy Table 1h.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Gartnerago obliquum	(Stradner, 1963) Noël, 1970 or Reinhardt, 1970.	Late Albian / Early Cenomanian - Late Maastrictian. CC9 - CC26.	Pu-5 and K-116.	Aaliji and Shiranish.
Helicolithus trabeculatus	(Gorka, 1957) Noël, 1970.	Late Aptian / Early Albian - Late CC7b - CC26.	K-116.	Shiranish.
Helicosphaera bramlettei	Müller, 1970.	Mid Eocene - Late Oligocene. NP17 - NP25 / CP14b - CP19b.	Mu-1.	Palani.
Helicosphaera compacta	Bramlette & Wilcoxon, 1967.	Mid Eocene - Mid Oligocene. NP16 - NP24 / CP14a - CP19a.	Ja-4 BH-8, Mu-1, K-85 and Pu-5.	Lower Fars (Transition Beds), Palani and Jaddala.
Helicosphaera euphratis	Haq, 1966.	Late Eocene - Mid Eocene. NP18 - NN5 / CP15a - CN4.	Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Ch-2 and Pu-5.	Lower Fars (Trancition Beds), Abu Ghar, Serikagni, Ibrahim, Baba Lm., Tarjil, Sheik Alas Lm., Palani, Pila Spi Lm., Jaddala, Dammam Lm., Rus Anhydrite and Khurmala Lm./ Aaliji.
Helicosphaera kampineri	Hay & Mohler in Hay *et al.*, 1967.	Early Miocene - Recent. NN2 - Recent / CP1a - Recent.	Pu-5.	Serikagni.
Helicosphaera mediterranea	Müller, 1981.	Early - Mid Miocene. NN1 - NN5 / CN1a - CN4.	Mu-1.	Lower Fars (Transition Beds) and Palani.
Helicosphaera minima	Bramlette & Wilcoxon, 1967.	Early Oligocene. NP21 - NP22 / CP16a - CP16c.	Mu-1.	Palani.
Helicosphaera scissura	Müller, 1981.	Early Miocene. NN1 - NN4 / CN1a - CN3.	Ja-4, BH-10 and Ra-1.	Abu Ghar, Ibrahim, Serikagni and Jaddala.

Figure 5.8 Taxonomy Table 1i.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Helicosphaera sellii	Bukry & Bramlette, 1969b.	Late Miocene - Late Pliocene. NN10 - NN18 / CN8a - CN12d.	Ja-4.	Lower Fars (Transition Beds).
Helicoshaera seminulum	Bramlette & Sullivan, 1961.	Early - Mid Eocene. NP12 - NP16 / CP10 - CP14a.	Ra-1.	Dammam Lm. and Rus Anhydrite.
Helicosphaera wilcoxonii	Gartner, 1971.	Late Eocene - Late Oligocene. NP18 - NP24 / CP15a - CP19a.	Pu-5.	Jaddala.
Heliolithus cantabriae	Perch-Nielsen, 1971b.	Mid - Late Palaeocene. NP5 - NP9 / CP4 - CP8a.	Ch-2.	Kolosh Clastics/ Aaliji.
Heliolithus kleinpellii	Sullivan, 1964.	Mid - Late Palaeocene. NP6 - NP9 / CP5 - CP8a.	Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Sinjar Lm./ Aaliji Boundary, Aaliji/ Kolosh Clatics and Aaliji.
Isthmolithus recurvus	Deflandre & Fert, 1954.	Late Eocene - Early Oligocene. NP19 - NP22 / CP15b - CP16c.	Ja-4.	Lower Fars (Transition Beds).
Lithraphidites spp.	Deflandre, 1963.	Early Berriasian - Late Maastrichtian. CC1 - CC26.	Ch-2, Pu-5 and K-116.	Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Lophodolithus nacens	Bramlette & Sullivan, 1961.	Late Palaeocene - Mid Eocene. NP9 - NP15 / CP8b - CP13a.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji and Aaliji.
Markalius apertus	Perch-Nielsen, 1979.	Early - Mid Palaeocene.	Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1j.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Markalius inversus	(Deflandre in Deflandre & Fert, 1954) Bramlette & Martini, 1964.	Late Maastrichtian - Mid Oligocene. CC26 - NP23 / CC26 - CP18.	BH-10, Ra-1, Ch-2, Pu-5 and K-116.	Ibrahim, Sinjar Lm., Jaddala, Dammam Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.
Micrantholithus flos	Deflandre in Deflandre & Fert, 1954.	Early - Mid Eocene. NP11 - NP14 / CP9b - CP12b.	Ch-2, Pu-5 and K-116.	Jaddala, Kolosh Clastics and Aaliji.
Micrantholithus pinguis	Bramlette & Sullivan, 1961.	Early Eocene. NP11 - NP14 / CP9b - CP12b	Ch-2.	Kolosh Clastics/ Aaliji.
Microrhabdulus decoratus	Deflandre, 1959.	Late Cenomanian - Late Maastrichtian. CC10 - CC26.	Ja-4 and Pu-5.	Lower Fars (Transition Beds), Aaliji and Shiranish.
Microrhabdulus undosus	Perch-Nielsen, 1973.	Mid - Late Maastrichtian. CC25a - CC26.	At-1, Ch-2 and K-116.	Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji and Shiranish.
Micula concava	(Stradner in Martini & Stradner, 1960) Verbeek, 1976.	Mid Santonian - Late Maastrictian. CC15 - CC26.	Ra-1, Ch-2 and Pu-5.	Abu Ghar, Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Micula murus	(Martini, 1961) Bukry, 1973c.	Late Maastrichtian. CC25c - CC26.	Ja-4, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Anah Lm., Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clatics.
Micula staurophora	(Gardet, 1955) Stradner, 1963.	Latest Portlandian / Tithonian - Late Maastrichtian. CC1a - CC26.	Ja-4, At-1, Pu-5 and K-116.	Lower Fars (Transition Beds), Avanah Lm./ Jaddala, Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1k.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Nannotetrina fulgens	(Martini & Stradner, 1960) Achuthan & Stradner, 1969.	Mid Eocene. NP15 / CP13a - CP13c.	K-85 and Pu-5.	Lower Fars (Transition Beds) and Jaddala.
Neochiastozygus denticulatus	(Perch-Nielsen, 1969) Perch-Nielsen, 1971b.	Mid - Late Palaeocene. NP4 - NP7 / CP3 - CP6.	Ch-2.	Kolosh Clastics/ Aaliji.
Neochiatozygus distentus	(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971b.	Late Palaeocene - Early Eocene. NP8 - NP11 / CP7 - CP9b.	Ja-4, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Kolosh Clastics, Aaliji and Tanjero Clastics.
Neochiastozygus junctus	(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971b.	Late Palaeocene - Early Eocene. NP7 - NP10 / CP6 - CP9a.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji, Aaliji and Tanjero Clastics.
Neochiastozygus modestus	Perch-Nielsen, 1971b.	Early - Mid Palaeocene. NP3 - NP5 / CP2 - CP4.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji and Aaliji.
Neochiastozygus perfectus	Perch-Nielsen, 1971b.	Early - Mid Palaeocene. NP4 - NP6 / CP3 - CP5.	Ch-2.	Kolosh Clastics/ Aaliji and Tanjero Clastics.
Neococcolithes dubius	(Deflandre, 1954) Black, 1967.	Early - Late Eocene. NP12 - NP18 / CP10 - CP4.	Ch-2.	Kolosh Clastics/ Aaliji.
Neococcolithes protenus	(Bramlette & Sullivan, 1961) Black, 1967.	Mid Palaeocene - Early Eocene. NP5 - NP12 / CP4 - CP10.	Ch-2.	Kolosh Clastics/ Aaliji.
Placozygus fibuliformis	(Rienhardt, 1964) Hoffmann, 1970b.		Ch-2, Pu-5 and K-116.	Kolosh Clastics/ Aaliji, Aaliji and Shiranish.
Placozygus sigmoides	(Bramlette & Sullivan, 1961) Romein, 1979.	Late Maastrichtian - Late Palaeocene. CC26 - NP9 / CC26 - CP8b.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji and Tanjero Clastics.

Figure 5.8 Taxonomy Table 11.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Pontosphaera spp.			Ja-4, BH-10, Mu-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Lower Fars (Basal Conglomerate), Serikagni, Ibrahim, Tarjil, Palani, Sinjar Lm., Jaddala, Dammam Lm., Rus Anhydrite, Kolosh Clastics and Kolosh Clastics/ Aaliji.
Pontosphaera multipora	(Kamptner, 1948) Roth, 1970.	Early - Mid Eocene. NP12 - NP14 / CP10 - CP12b.	BH-10, Mu-1, Ra-1 and Pu-5.	Ibrahim, Palani, Dammam Lm., Rus Anhydrite and Jaddala.
Prediscosphaera cretacea	(Arkhangelskelsky, 1912) Gartner, 1968.	Early Campanian - Late Maastrichtian. CC18b - CC26.	Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Pila Spi Lm., Sinjar Lm., Kolosh Clastics, Aaliji, Shiranish and Tanjero Clastics.
Prediscosphaera grandis	Perch-Nielsen, 1979.	Early - Late Maastrichtian. CC23b - CC26.	Ja-4, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Ibrahim, Kolosh Clastics / Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Prediscosphaera stoveri	(Perch-Nielsen, 1968) Shafik & Stradner, 1971.	Late Campanian - Late Maastrichtian. CC21b - CC26.	Pu-5 and K-116.	Shiranish.
Prinsius bisulcus	(Stradner, 1963) Hay & Mohler, 1967.	Mid - Late Palaeocene. NP4 - NP9 / CP3 - CP8a.	Ch-2, Pu-5 and K-116.	Lower Fars (Basal Conglomerate Beds), Pila Spi Lm., Sinjar Lm., Kolosh Clastics, Aaliji, Shiranish and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1m.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Prinsius dimorphosus	(Perch-Nielsen, 1969) Perch-Nielsen, 1977.	Early - Mid Palaeocene. NP2 - NP4 / CP1b - CP2.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.
Prinsius martinii	(Perch-Nielsen, 1969) Haq, 1971.	Early - Mid Palaeocene. NP3 - NP9 / CP2 - CP8b.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.
Pyrocyclus hermosus	Roth & Hay, 1967.	Early Oligocene - Mid Pliocene.	Ja-4 and Pu-5.	Serikagni, Palani and Jaddala.
Quadrum gartneri	Prins & Perch-Nielsen in Manivit *et al.*, 1977.	Early Turonian - Early Campanian. CC11 - CC17.	Ja-4, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Euphrates Lm., Anah Lm., Sinjar Lm., Kolosh Clastics, Aaliji, Shiranish and Tanjero Clastics.
Quadrum gothicum	(Deflandre, 1959) Prins & Perch-Nielsen in Manivit *et al.*, 1977.	Late Santonian - Early Maastrichtian. CC16 - CC23b.	Ch-2, Pu-5 and K-116.	Sinjar Lm., Kolosh Clastics/ Aaliji, Aaliji and Shiranish.
Quadrum sissinghii	Perch-Nielsen, 1984.	Mid Campanian - Early Maastrichtian. CC21a - CC23b.	Ch-2.	Kolosh Clastics/ Aaliji.
Quadrum trifidum	(Stradner in Stradner & Papp, 1961) Prins & Perch-Nielsen in Manivit *et al.*, 1977.	Late Campanian - Early Maastrichtian. CC22a - CC23b.	Ch-2 and Pu-5.	Kolosh Clastics/ Aaliji, Aaliji and Shiranish.

Figure 5.8 Taxonomy Table 1n.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Reticulofenestra bisecta	(Hay, Mohler & Wade, 1966) Roth, 1970.	Mid / Late Eocene - Late Oligocene. NP16 - NP25 / CP14a - CP19b.	Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Ch-2 and Pu-5.	Lower Fars (Transition Beds), Euphrates Lm., Dhiban Anhydrite, Serikagni, Anah Lm., Ibrahim, Baba Lm., Tarjil, Shiek Alas Lm., Palani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Sinjar Lm., Khurmala Lm./ Aaliji, Kolosh Clastics/ Aaliji and Aaliji.
Reticulofenestra callida	(Perch - Nielsen, 1971c) Bybell, 1975.	Mid Eocene. NP14 - NP15 / CP13a - CP13b.	Ja-4, Mu-1, K-85, Ra-1 and Pu-5.	Lower Fars (Transition Beds), Palani, Jaddala, Rus Anhydrite and Aaliji.
Reticulofenstra dictyoda	(Deflandre in Deflandre & Fert, 1954) Stradner in Stradner & Edwards, 1968.	Early - Mid Eocene. NP13 - NP16 / CP11 - CP14a.	Mu-1, At-1, K-85, Ra-1, Pu-5 and K-116.	Palani/ Jaddala, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji, Umm Er Radhuma and Tayarat Lm.
Reticulofenestra haqii	Backman, 1978.	Mid Miocene.	Ja-4, BH-10, BH-8 and Ra-1.	Lower Fars (Transition Beds), Abu Ghar, Euphrates Lm., Anah Lm. and Ibrahim.
Reticulofenestra hillae	Bukry & Percival, 1971.	Mid Eocene - Early Oligocene. NP17 - NP22 / CP14a - CP16c.	Mu-1.	Palani.

Figure 5.8 Taxonomy Table 1o.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Reticulofenestra minuta	Roth, 1970.	Late Eocene - Mid Oligocene. NP18 - NP23 / CP15a - CP18.	Ja-4, BH-10, BH-8, Mu-1, Ra-1, Ch-2 and Pu-5.	Lower Fars (Transition Beds & Basal Conglomerate), Abu Ghar, Euphrates Lm., Serikagni, Anah Lm., Palani, Pila Spi Lm., Jaddala and Dammam Lm.
Reticulofenestra productus	(Kamptner,1963) Backman, 1980.	Mid Miocene.	Ja-4, BH-10, BH-8, Ra-1 and Ch-2.	Lower Fars (Transition Beds & Basal Conglomerate), Abu Ghar, Dhiban Anhydrite, Euphrates Lm., Serikagni, Anah Lm., Ibrahim, Pila Spi Lm., Sinjar Lm., Dammam Lm. and Kolosh Clastics/ Aaliji.
Reticulofenestra pseudoumbilica	(Gartner, 1967) Gartner, 1969.	Mid Miocene - Early Pliocene. NN6 - NN15 / CN5a - CN11b.	Ja-4, Ra-1 and Ch-2.	Lower Fars (Basal Conglomerate & Transition Beds), Abu Ghar and Pila Spi Lm.
Reticulofenestra scrippsae	(Bukry & Percival, 1971) Roth, 1973.	Mid Eocene - Late Oligocene. NP16 - NP25 / CP14a - CP19b.	Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Pu-5 and K-116.	Lower Fars (Transition Beds), Serikagni, Ibrahim, Bajawan Lm., Baba Lm., Tarjil, Shiek Alas Lm., Palani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji, Umm Er Radhuma and Tayarat Lm.

Figure 5.8 Taxonomy Table 1p.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Reticulofenestra umbilica	(Levin, 1965) Martini & Ritzkowski, 1968.	Mid Eocene - Early Oligocene. NP15 - NP22 / CP13c - CP16c.	Ja-4, Mu-1, At-1, K-85, Ra-1, Pu-5 and K-116.	Lower Fars (Transition Beds), Tarjil, Palani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Kolosh Clastics, Khurmala Lm./ Aaliji, Umm Er Radhuma and Tayarat Lm.
Rhabdolithus spp.			Ja-4, Mu-1, K-85, Ra-1, Pu-5 and Ch-2.	Lower Fars (Transition Beds), Tarjil, Palani, Jaddala, Dammam Lm., Rus Anhydrite and Sinjar Lm.
Rhabdolithus solus	Perch-Nielsen, 1971c.	Early Eocene. NP12 - NP13 / CP10 - CP11.	Ch-2.	Kolosh Clastics/ Aaliji.
Rhabdolithus tenuis	Bramlette & Sullivan, 1961.	Early Eocene - Mid Oligocene. NP12 - NP23 / CP10 - CP18.	Mu-1 and K-85.	Palani.
Rhabdolithus truncata	Bramlette & Sullivan, 1961.	Early Eocene. NP12 - NP13 / CP10 - CP11.	Ch-2.	Kolosh Clastics/ Aaliji.
Rhomboaster bitrifida	Romein, 1979.	Late Palaeocene - Early Eocene. NP9 - NP10 / CP8b - CP9a.	Ch-2.	Kolosh Clastics/ Aaliji.
Scapholithus rhombiformis	Hay & Mohler, 1967.	Palaeocene - Eocene.	Pu-5 and Ch-2.	Jaddala, Kolosh Clastics/ Aaliji, Aaliji and Tanjero Clastics.
Sphenolithus abies	Deflandre in Deflandre & Fert, 1954.	Mid Miocene - Early Pliocene. NN9 - NN15 / CN7a - CN11b.	Ja-4.	Lower Fars (Transition Beds).

Figure 5.8 Taxonomy Table 1q.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Sphenolithus anarrhopus	Bukry & Bramlette, 1969a.	Mid Palaeocene - Early Eocene. NP4 - NP11 / CP3 - CP9b.	Pu-5, K-116 and Ch-2.	Jaddala, Sinjar Lm., Kolosh Clastics, Aaliji and Shiranish.
Sphenolithus ciperoensis	Bramlette & Wilcoxon, 1967.	Late Oligocene - Early Miocene. NP24 - NN1 / CP19a - CN1a.	Ja-4.	Lower Fars (Transition Beds).
Sphenolithus conicus	Bukry, 1971.	Early Miocene. NN1 - NN3 / CN1a - CN2.	Ja-4.	Lower Fars (Transition Beds).
Sphenolithus conspicuus	Martini, 1976.	Early Eocene. NP11 - NP13 / CP9b - CP11.	Ch-2.	Kolosh Clastics/ Aaliji.
Sphenolithus dissimilis	Bukry & Percival, 1971.	Late Oligocene - Early Miocene. NP24 - NN2 / CP19a - CN1c.	Ja-4 and Pu-5.	Serikagni.
Sphenolithus distentus	(Martini, 1965) Bramlette & Wilcoxon, 1967.	Mid - Late Oligocene. NP23 - NP24 / CP18 - CP19a.	BH-10.	Ibrahim.
Sphenolithus editus	Perch-Nielsen in Perch-Nielsen et al., 1978.	Early Eocene. NP11 - NP13 / CP9b - CP11.	K-116.	Kolosh Clastics and Kolosh Clastics/ Aaliji.
Sphenolithus elongatus	Perch-Nielsen, 1980.	Mid Eocene. NP14 - NP15 / CP12a - CP13c.	K-116.	Kolosh Clastics.
Sphenolithus furcatolithoides	Locker, 1967.	Mid Eocene. NP15 - NP16 / CP13a - CP14a.	Pu-5 and K-116.	Jaddala and Kolosh Clastics.
Sphenolithus heteromorphus	Deflandre, 1953.	Early - Mid Miocene. NN4 - NN5 / CN3 - CN4.	Ja-4, BH-10, BH-8 and Ch-2.	Lower Fars (Transition Beds), Ibrahim, Serikagni and Pila Spi Lm.
Sphenolithus moriformis	(Brönnimann & Stradner, 1960) Bramlette & Wilcoxon, 1967.	Early Eocene - Late Miocene. NP12 - NN9 / CP10 - CN9a.	Ja-4 and Pu-5.	Lower Fars (Transition Beds), Palani and Jaddala.

Figure 5.8 Taxonomy Table 1r.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Sphenolithus moriformis Group			Ja-4, BH-10, BH-8, Mu-1, At-1, K-85, Ra-1, Ch-2, Pu-5 and K-116.	Lower Fars (Transition Beds), Dhiban Anhydrite, Euphrates Lm., Serikagni, Bajawan Lm., Baba Lm., Tarjil, Anah Lm., Ibrahim, Shiek Alas Lm., Palani, Pila Spi Lm., Avanah Lm. / Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Sinjar Lm., Kolosh Clastics, Khurmala Lm. / Aaliji, Aaliji, Umm Er Radhuma, Shiranish and Tanjero Clastics.
Sphenolithus predistentus	Bramlette & Wilcoxon, 1967.	Mid Eocene - Late Oligocene. NP14 - NP24 / CP12b - CP19a.	Ja-4, BH-8, Mu-1,K-85, Pu-5 and Ch-2.	Lower Fars (Transition Beds), Baba Lm., Tarjil, Palani, Jaddala and Sinjar Lm.
Sphenolithus radians	Deflandre in Grassé, 1952.	Early - Late Eocene. NP11 - NP19 / CP9b - CP15b.	Ja-4, BH-10, At-1, K-85, Ra-1, Pu-5, K-116 and Ch-2.	Lower Fars (Transition Beds) Ibrahim, Tarjil, Palani, Avanah Lm./ Jaddala, Jaddala, Dammam Lm., Rus Anhydrite, Sinjar Lm., Kolosh Clastics, Khurmala Lm./ Aaliji and Aaliji.
Sphenolithus spiniger	Bukry, 1971.	Mid Eocene. NP14 - NP15 / CP12b - CP13b.	Pu-5 and K-116.	Jaddala, Kolosh Clastics, Aaliji and Shiranish.

Figure 5.8 Taxonomy Table 1s.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Stradneria crenulata	(Bramlette & Martini, 1964) Noël, 1970.	Late Berriasian - Late Maastrichtian. CC2 - CC26.	Pu-5, K-116 and Ch-2.	Lower Fars (Transition Beds), Sinjar Lm., Kolosh Clastics, Aaliji, Shiranish, and Tanjero Clastics.
Thoracosphaera operculata	Bramlette & Martini, 1964.	Late Createaceous - Early Eocene. CC26 - NP10 / CC26 - CP9a.	Ja-4, BH-8, Mu-1, K-85, Pu-5 and Ch-2.	Lower Fars (Transition Beds), Tarjil, Palani, Jaddala, Sinjar Lm., Kolosh Clastics/ Aaliji and Aaliji.
Toweius eminens	(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971a.	Late Palaeocene - Early Eocene. NP7 - NP10 / CP6 - CP9a.	BH-10, Pu-5 and Ch-2.	Anah Lm., Sinjar Lm., Kolosh Clastics, Aaliji, Shiranish and Tanjero Clastics.
Toweius tovae	Perch-Nielsen, 1971a.	Late Palaeocene. NP9 / CP8a - CP8b.	Pu-5 and Ch-2.	Sinjar Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.
Toweius pertusus	(Sullivan, 1965) Romein, 1979.	Mid Palaeocene - Early Eocene. NP6 - NP12 / CP5 - CP10.	Ch-2.	Kolosh Clastics/ Aaliji.
Tranolithus minimus	(Bukry, 1969) Perch-Nielsen, 1984.	(Cenomanian) Santonian - Maastrichtian. (CC10) CC14 - CC26.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji, Shiranish and Tanjero Clastics.
Tranversopontis obliquipons	(Deflandre in Deflandre & Fert, 1954) Hay, Mohler & Wade, 1966.	Early - Mid Eocene. NP13 - NP14 / CP11 - CP12b.	Mu-1 and Ra-1.	Palani and Rus Anhydrite.
Tranversopontis pulcher	(Deflandre in Deflandre & Fert, 1954) Perch-Nielsen, 1967.	Early - Mid Eocene. NP11 - NP15 / CP9b - CP13a.	Ch-2 and K-116.	Kolosh Clastics/ Aaliji.
Tranversopontis rectipons	(Haq, 1968) Roth, 1970.	Early - Mid Eocene. NP11 - NP15 / CP9b - CP13a.	Ja-4, K-85 and Ra-1.	Lower Fars (Transition Beds), Jaddala and Rus Anhydrite.

Figure 5.8 Taxonomy Table 1t.

TAXON.	AUTHOR(S).	PUBLISHED AGE RANGE.	WELL.	FORMATION(S).
Tribrachiatus contortus	(Stradner, 1958) Bukry, 1972.	Early Eocene. NP10/ CP9a.	Ch-2.	Kolosh Clastics/ Aaliji.
Tribrachiatus orthostylus	Shamrai, 1963.	Early - Mid Eocene. NP10 - NP14 / CP9a - CP12b.	Pu-5, Ch-2 and K-116.	Lower Fars (Transition Beds), Jaddala/ Aaliji Boundary, Kolosh Clastics and Aaliji.
Watznaueria barnesae	(Black in Black & Barnes, 1959) Perch-Nielsen, 1968.	Early Bajocian - Late Maastrichtian. NJ9 - CC26.	At-1, Pu-5, Ch-2 and K-116.	Pila Spi Lm., Avanah Lm./ Jaddala, Sinjar Lm., Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Watznaueria manivitae	(Forchheimer, 1972) Bukry, 1973d.	Late Maastrichtian. CC26.	Ja-4, At-1, Ra-1, Pu-5, Ch-2 and K-116.	Lower Fars (Transition Beds), Abu Ghar, Sinjar Lm., Kolosh Clastics, Khurmala Lm./ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Zygodiscus bramlettei	Perch-Nielsen, 1981.	Mid - Late Palaeocene. NP5 - NP9 / CP4 - CP8b.	Ja-4, Pu-5, Ch-2 and K-116.	Lower Fars (Transition Beds), Kolosh Clastics/ Aaliji, Aaliji, Shiranish and Tanjero Clastics.
Zygrhablithus bijugatus	(Deflandre in Deflandre & Fert, 1954) Deflandre, 1959.	Early Eocene - Early Miocene. NP11 - NN1 / CP9b - CP1a.	Ja-4, BH-8, Mu-1, K-85, Pu-5, Ch-2 and K-116.	Lower Fars (Transition Beds), Euphrates Lm., Serikagni, Anah Lm., Ibrahim, Baba Lm., Baba Lm./ Tarjil, Palani, Jaddala, Dammam Lm., Rus Anhy., Sinjar Lm., Kolosh Clastics, Aaliji and Tanjero Clastics.

Figure 5.8 Taxonomy Table 1u.

Plate No. 1

Marker Species.

PLATE No. 1

The scale of the nannofossils illustrated in the photomicrographs are X 1800 unless otherwise stated. The descriptions below also contains some acronyms:

UCL - University College London Film Archive (Film No./ Negative No.).
XPL - Crossed Polars.
PPL - Plane Polarized Light.
(R) - Reworked Occurrence.
(C) - Caved Occurrence.

Marker Species:

1. ***Cyclicargolithus abisectus.*** Distal view in XPL. Zone IT2, Late Oligocene, Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3491/ 4.
2. ***Reticulofenestra bisecta.*** (a) Distal view in PPL, (b) Distal view in XPL. Zone IT6, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 29, UCL 3270/ 3, UCL 3254/ 25.
3. ***Sphenolithus distentus.*** (a) and (b) Side views at 90° and 45° in XPL. Mid Miocene (R), Jambur No. 4, Lower Fars Formation (Transition Beds), Sample Ja-4/ 1, UCL 3271/ 22, UCL 3254/ 2.
4. ***Sphenolithus predistentus.*** (a) and (b) Side views at 90° and 45° in XPL, (c) Side view at 45° in XPL. Early Oligocene and Mid Miocene (R), Kirkuk No. 85 and Jambur No. 4, Palani and Lower Fars Formation (Transition Beds), Sample Nos. K-85/ 16 (a and b) and Ja-4/ 1 (c), UCL 3253/ 35 and 36, and UCL XXX1/ 5.
5. ***Ericsonia subdisticha.*** Distal view in XPL. Zone IT5, Early Oligocene, Kirkuk No. 85, Palani Formation, Sample No. K-85/ 15, UCL 3698/ 3 (X 4000).
6. ***Reticulofenestra dictyoda.*** (a) Distal view in PPL, (b) Distal view in XPL. Zone IT7, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 33, UCL 3254/ 13 and 14 (X 2200).
7. ***Reticulofenestra callida.*** Distal view in XPL. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 26, UCL 3489/ 12.
8. ***Discoaster kuepperi.*** (a) Distal view in PPL, (b) Side view in XPL. Zone IT8c, Early Eocene, Kirkuk No. 116, Kolosh Clastics Formation, Sample No. K-116/ 1, UCL 3617/ 11 and 12.
9. ***Sphenolithus conspicuus.*** (a) and (b) Side views at 90° and 45° in XPL respectively. Zone IT8b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 59, UCL 3617/ 30 and 31 (X2600).
10. ***Tribrachiatus orthostylus*** **Type B.** Distal view in PPL. Zone IT8c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 83, UCL 3602/ 14 (X 1200).
11. ***Tribrachiatus orthostylus*** **Type A.** Distal view in PPL. Zone IT8c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 76, UCL 3645/ 8 (X 1200).
12. ***Tribrachiatus contortus*** **Type A.** Distal view in PPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 87, UCL 3602/ 14 (X 1000).
13. ***Discoaster multiradiatus.*** Distal view in PPL. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3602/ 2.
14. ***Discoaster binodosus binodosus.*** Distal views in PPL (a) Common 7 ray and (b) Less common 9 ray forms. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample Nos. Ch-2/ 89 and Ch-2/ 91, UCL 3645/ 10, UCL 3601/ 16 respectively (X 1400).
15. ***Rhomboaster bitrifida.*** Distal view in PPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 93, UCL 3601/ 11 (X 1600).
16. ***Fasciculithus tympaniformis.*** Side view in XPL. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 9.
17. ***Fasciculithus hayi.*** Side view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 7, UCL 3270/ 32.
18. ***Heliolithus kleinpellii.*** Distal view in XPL. Zone IT11, Mid to Late Paleocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 40, UCL 3493/ 12 (X 1300).
19. ***Fasciculithus pileatus.*** Side view in XPL. Zone IT12, Mid Palaeocene, Pulkhana No. 5, Aaliji Formation, Pu-5/ 42, UCL 3503/ 27.
20. ***Micula murus.*** XPL. Zone IT13, Late Cretaceous, Pulkhana No. 5, Shiranish Formation, Pu-5/ 46, UCL 3502/ 16.

PLATE 1

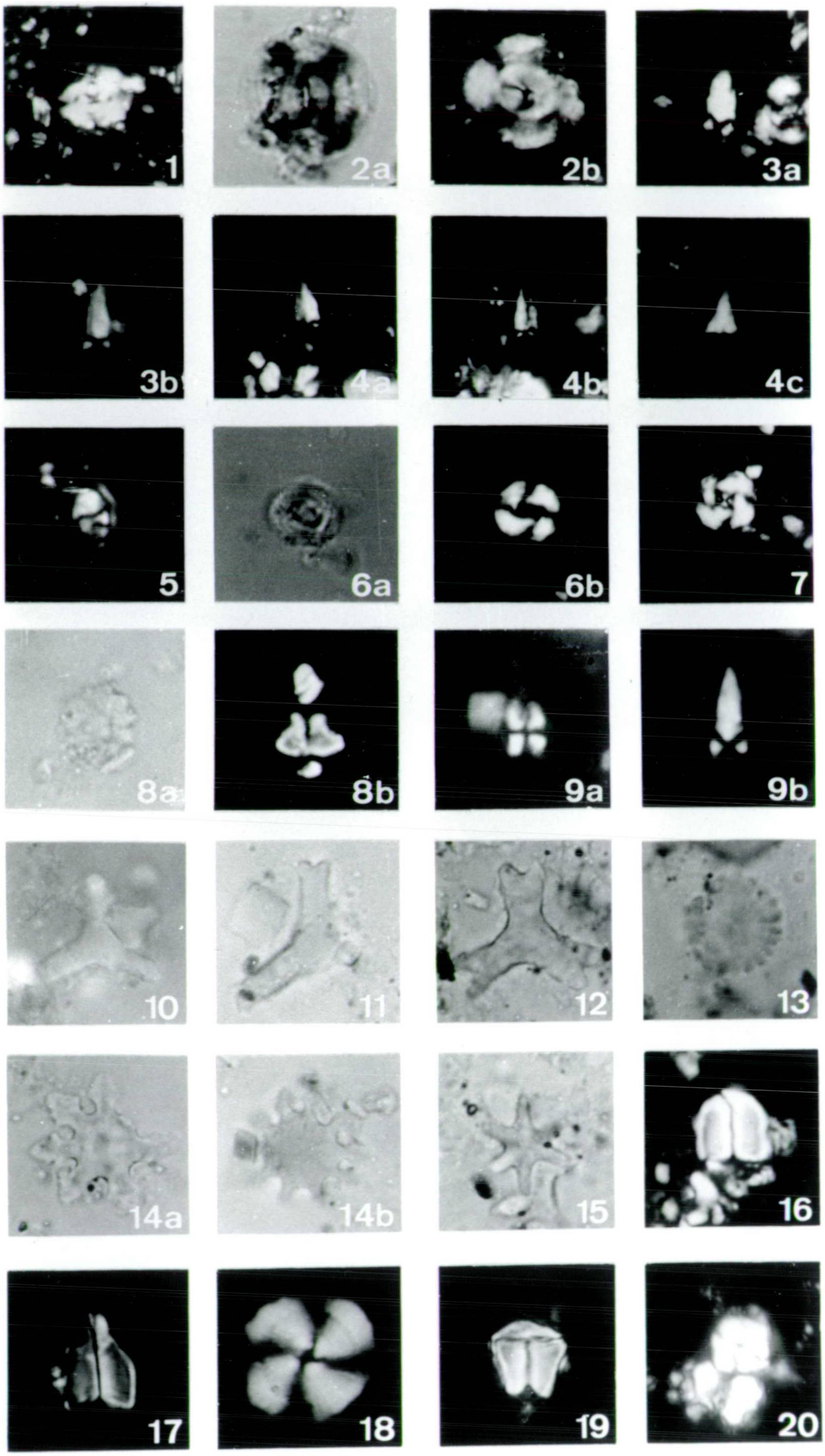

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Plate No. 2

Cretaceous Taxa.

PLATE No. 2

Cretaceous Taxa:

1. ***Arkhangelskiella cymbiformis***. Distal view in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3502/ 2.
2. ***Aspidolithus parca parca***. Distal view in XPL. Zone IT12, Mid Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 25.
3. ***Calculites ovalis***. 90° to XPL. Zone IT2, Late Oligocene (R), Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3505/ 16.
4. ***Cribrosphaerella daniae***. XPL. Zone IT11, Mid to Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 40, UCL 3493/ 29.
5. ***Cribrosphaerella ehrenbergii***. XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3502/ 1.
6. ***Eiffellithus eximius***. XPL. Zone IT11, Mid to Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 40, UCL 3493/ 8.
7. ***Eiffellithus gorkae***. XPL. Zone IT10, Early Eocene (R), Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 92, UCL 3645/ 13.
8. ***Eiffellithus turriseiffelii***. XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3503/ 1.
9. ***Gartnerago obliquum***. Distal view in XPL. Zone IT10, Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3488/ 11 (X 1200).
10. ***Lithraphidites* spp.** . Side view at 90° in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3503/ 21.
11. ***Microrhabdulus decoratus***. Side view at 90° in XPL. Zone IT10, Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 11 (X 1500).
12. ***Microrhabdulus undosus***. (a) and (b) Side views at 90° and 45° in XPL respectively. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3503/ 10 and 11 respectively (X 1200).
13. ***Micula concava***. Distal view at 90° in XPL. Zone IT10a, Early Eocene (R), Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 88, UCL 3645/ 9 (X 3200).
14. ***Micula staurophora***. (a) and (b) Distal view at 90° and 45° in XPL respectively. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3503/ 10 and 11.
15. ***Placozygus fibuliformis***. Distal view in XPL. Zone IT13, Late Maastrichtian, Well Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3502/ 6 (X 3200).
16. ***Prediscosphaera cretacea***. Distal view in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3502/ 20.
17. ***Prediscosphaera grandis***. Distal view in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3493/ 35.
18. ***Prediscosphaera stoveri***. Distal view in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46, UCL 3505/ 33.
19. ***Quadrum gartneri***. Distal view at 90° in XPL. Zone IT11, Mid to Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 40, UCL 3493/ 15.
20. ***Quadrum gothicum***. Distal view at 90° in XPL. Zone IT11, Mid to Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 40, UCL 3487/ 27.
21. ***Quadrum sissinghii***. Distal view at 90° in XPL. Zone IT10a, Late Palaeocene (R), Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 7, UCL 3586/ 14.
22. ***Quadrum trifidum***. Distal view at 90° in XPL. Zone IT2, Late Oligocene (R), Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3505/ 14.
23. ***Stradneria crenulata***. Distal view in XPL. Zone IT13, Late Maastrichtian, Pulkhana No. 5, Shiranish Formation, Sample No. Pu-5/ 46.
24. ***Tranolithus minimus***. Distal view in XPL. Zone IT9b, Early Eocene (R), Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3602/ 7 (X 2200).
25. ***Watznaueria barnesae***. Distal view in XPL. Zone IT10, Late Palaeocene (R), Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3488/ 15.
26. ***Watznaueria manivitae***. Distal view in XPL. Zone IT9b, Early Eocene (R), Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Ch-2/ 103, UCL 3601/ 34.

PLATE 2

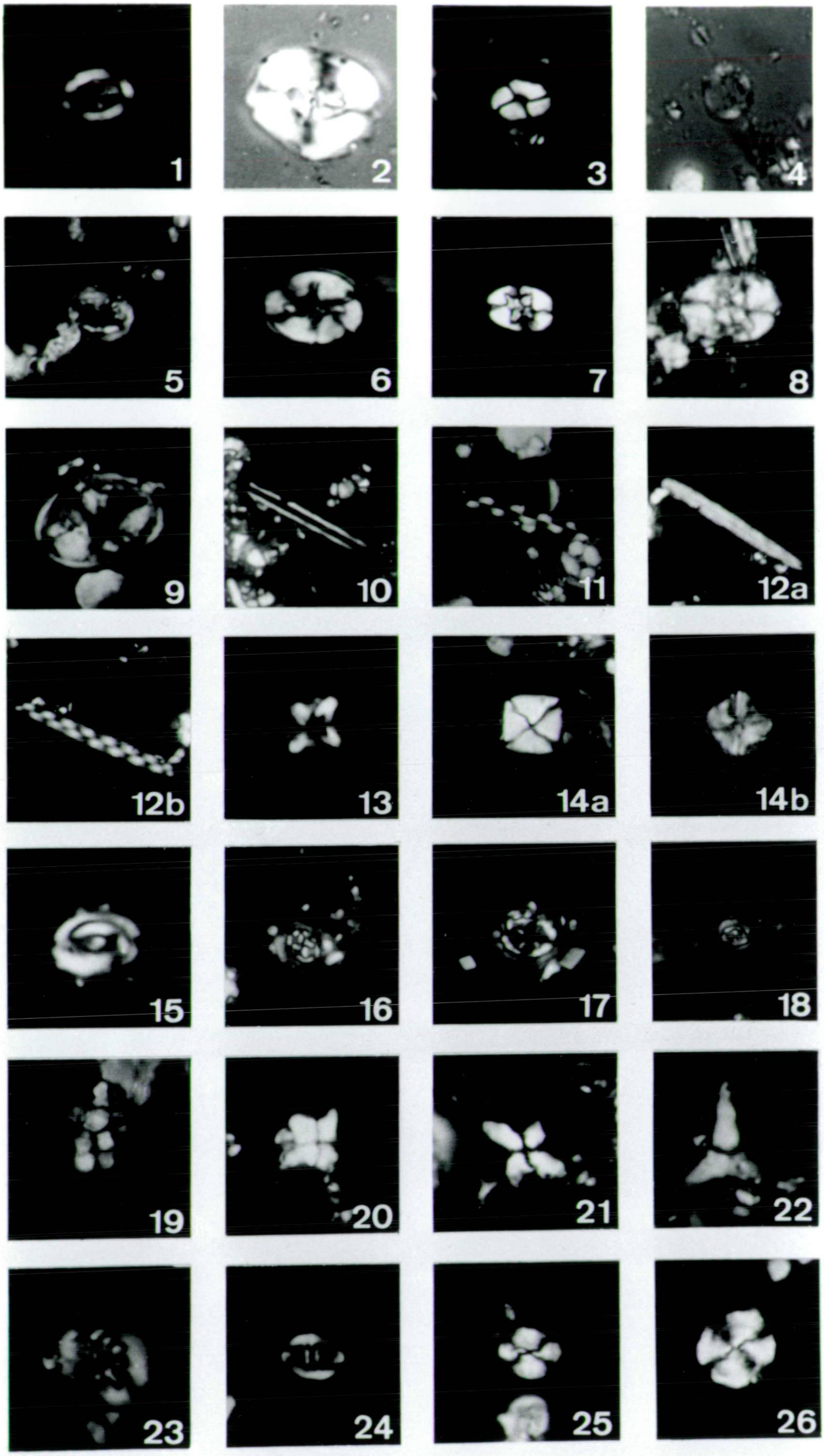
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Plate No. 3

Zygodiscaceae,

Pontosphaeraceae,

Braarudosphaeraceae

& Thoracosphaeraceae.

PLATE No. 3

Zygodiscaceae Hay & Mohler (1967):

1. ***Isthmolithus recurvus***. Distal view in PPL. Mid Miocene (R), Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 23.
2. ***Lophodolithus nacens***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3602/ 15 and 16.
3. ***Neochiastozygus distentus***. Distal view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 7, UCL 3586/ 13.
4. ***Neochiastozygus chiastus***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 91, UCL 3601/ 1 and 2.
5. ***Neochiastozygus junctus***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 91, UCL 3601/ 14 and 15.
6. ***Neochiastozygus modestus***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT10, Late Palaeocene, Well Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 117, UCL 3681/ 1 and 2.
7. ***Neochiastozygus perfectus***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT10, Late Palaeocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 121, UCL 3648/ 4 and 6.
8. ***Neococcolithes dubius***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3602/ 8 and 9.
9. ***Neococcolithes protenus***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3602/ 22 and 23.
10. ***Placozygus sigmoides***. (a) and (b) Distal view in PPL and XPL respectively. Zone IT8a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 45, UCL 3617/ 34 and 35.
11. ***Zygodiscus bramlettei***. Distal view in XPL. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 13.

Pontosphaeraceae Lemmermann (1908):

12. ***Pontosphaera* spp.** Distal view in XPL. Zone IT2, Late Oligocene, Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3491/ 24.
13. ***Pontosphaera multipora***. Distal view in XPL. Mid Miocene (R), Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 3, UCL 3751/ 10.
14. ***Traversopontis obliquipons***. Distal view in XPL. Zone IT6, Mid Eocene, Rachi No. 1, Dammam Limestone Formation, Sample No. Ra-1/ 28, UCL 3681/ 22.
15. ***Traversopontis pulcher***. Distal view in XPL. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 95, UCL 3645/ 16.
16. ***Traversopontis rectipons***. Distal view in XPL. Zone IT7, Mid Eocene, Rachi No. 1, Rus Anhydrite Formation, Sample No. Ra-1/ 30, UCL 3681/ 28.

Braarudosphaeraceae Deflandre (1947):

17. ***Braarudosphaera bigelowii***. Distal view in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 91, UCL 3601/ 18.
18. ***Micrantholithius flos***. Distal view in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 91, UCL 3601/ 24.
19. ***Micrantholithius pinguis***. Distal view in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 89.

Thoracosphaeraceae Schiller (1930):

20. ***Thoracosphaera operculata***. Proximal view in XPL showing archeopyle. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 21.

PLATE 3

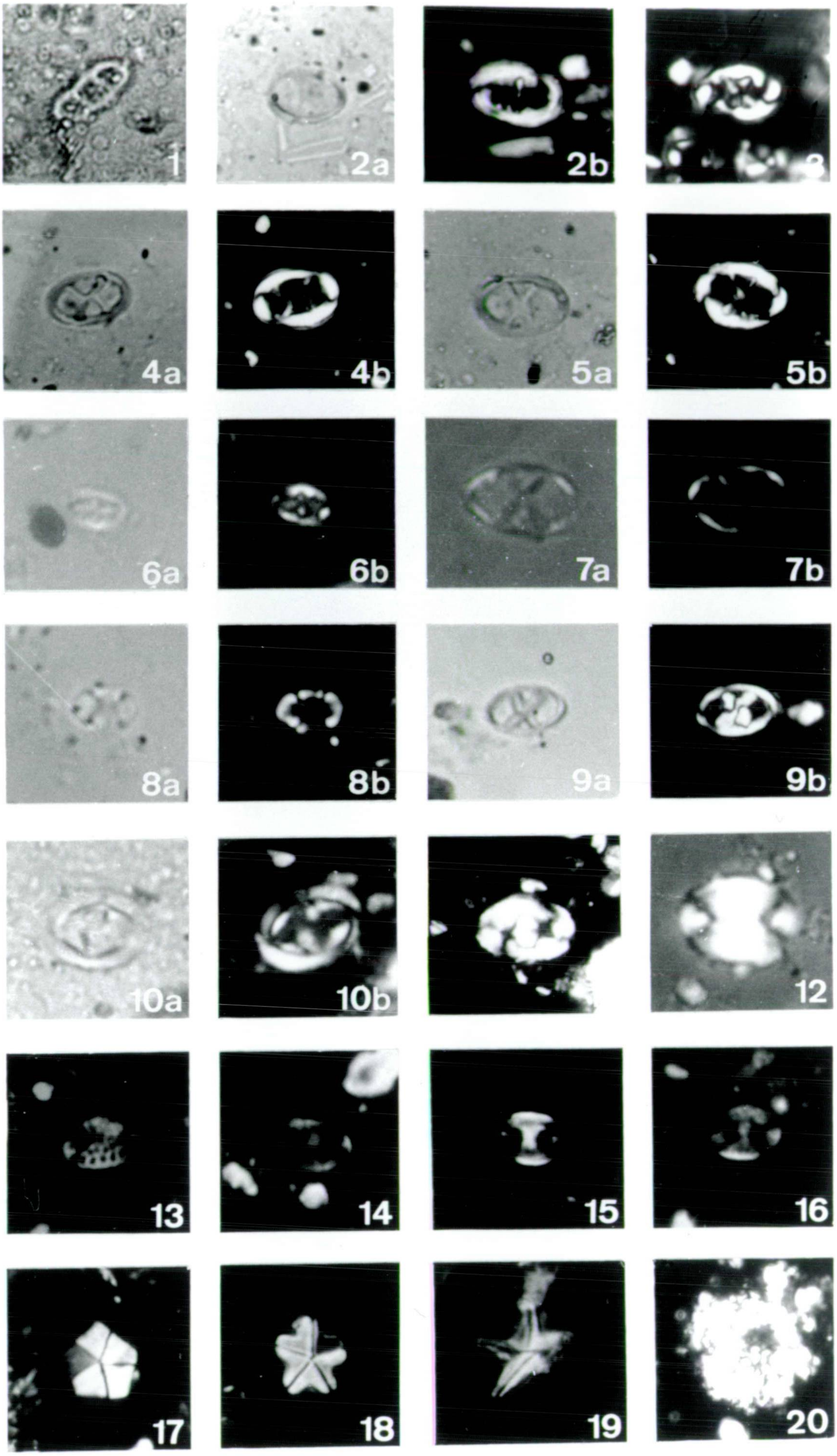
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Plate No. 4

Discoasteraceae,

Helicosphaeraceae

& Incertae sedis.

PLATE No. 4

Discoasteraceae Tan (1927):

1. ***Discoaster adamanteus***. Distal view in PPL. Zone IT3, Late Oligocene, Bai Hassan No. 10, Ibrahim Formation, Sample No. BH-10/ 39, UCL 3743/ 11.
2. ***Discoaster barbadiensis***. Distal view in PPL. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 26, UCL 3489/ 36.
3. ***Discoaster deflandrei***. Distal view in PPL. Zone IT2, Late Oligocene, Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3491/ 13.
4. ***Discoaster diastypus***. Distal view in PPL. Zone IT9c, Early Eocene, Chemechemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 104, UCL 3645/ 22.
5. ***Discoaster druggii***. Distal view in PPL. Mid Miocene, Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 19.
6. ***Discoaster falcatus***. Distal view in PPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 91, UCL 3601/ 29.
7. ***Discoaster gemmeus***. Distal view in PPL. Zone IT6, Mid Eocene, Rachi No. 2, Dammam Limestone Formation, Sample No. Ra-1/ 28, UCL 3681/ 23.
8. ***Discoaster lodoensis***. Distal view in PPL. Zone IT8 and IT9, Early Eocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 36, UCL 3504/ 27.
9. ***Discoaster mahmoudii***. Distal view in PPL. Zone IT8 and IT9, Early Eocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 36, UCL 3504/ 31.
10. ***Discoaster mohleri***. Distal view in PPL. Zone IT10, Late Palaeocene Eocene, Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 14, UCL 3587/ 10.
11. ***Discoaster saipanensis***. Distal view in PPL. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 26, UCL 3491/ 27.
12. ***Discoaster salisburgensis***. Distal view in PPL. Zone IT9a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 74, UCL 3645/ 9.
13. ***Discoaster cf. D. stella***. Distal view in PPL. Zone IT9a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 73, UCL 3599/ 15.
14. ***Discoaster tanii***. Distal view in PPL. Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, UCL 3340/ 13.
15. ***Discoaster tanii nodifer***. Distal view in PPL. Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, UCL 3340/ 12.
16. ***Discoaster wemmelensis***. Distal view in PPL. Zone IT6, Mid Eocene, Rachi No. 2, Dammam Limestone Formation, Sample No. Ra-1/ 27, UCL 3681/ 20.

Heliocosphaeraceae Black (1971a):

17. ***Helicosphaera bramlettei***. Distal view in XPL. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 12, UCL 3698/ 15.
18. ***Helicosphaera compacta***. Distal view in XPL. Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, UCL 3489/ 23.
19. ***Helicosphaera euphratis***. Distal view in XPL. Zone IT2, Late Oligocene, Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3491/ 2.
20. ***Helicospheara kamptneri***. Distal view in XPL. Zone IT2, Late Oligocene (C), Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3617/ 33.
21. ***Helicosphaera mediterranea***. Distal view in XPL. Mid Miocene, Chemechemal No. 2, Lower Fars Formation (Transition Beds), Ch-2/ 1, UCL 3681/ 13.
22. ***Helicosphaera minima***. Distal view in XPL. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 12, UCL 3698/ 16.
23. ***Helicosphaera scissura***. Distal view in XPL. Mid Miocene, Jambur No.4, Lower Fars Formation (Transition Beds), Ja-4/ 1, UCL 3751/ 7.
24. ***Helicosphaera sellii***. Distal view in XPL. Mid Miocene, Jambur No.4, Lower Fars Formation (Transition Beds), Ja-4/ 1, UCL 3751/ 20.
25. ***Helicosphaera seminulum***. Distal view in XPL. Zone IT8 and IT9, Early Eocene, Pulkhana No. 5, Aaliji Formation, Pu-5/ 36, UCL 3504/ 12.
26. ***Helicosphaera wilcoxonii***. Distal view in XPL. Zone IT5, Early Oligocene, Pulkhana No. 5, Palani Formation, Pu-5/ 2, UCL 3515(A)/ 23.

Incertae sedis:

27. ***Ellipsolithus distichus***. Distal view in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 91, UCL 3601/ 28.
28. ***Ellipsolithus macellus***. Distal view in XPL. Zone IT9a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2/ 73, UCL 3599/ 20.

PLATE 4

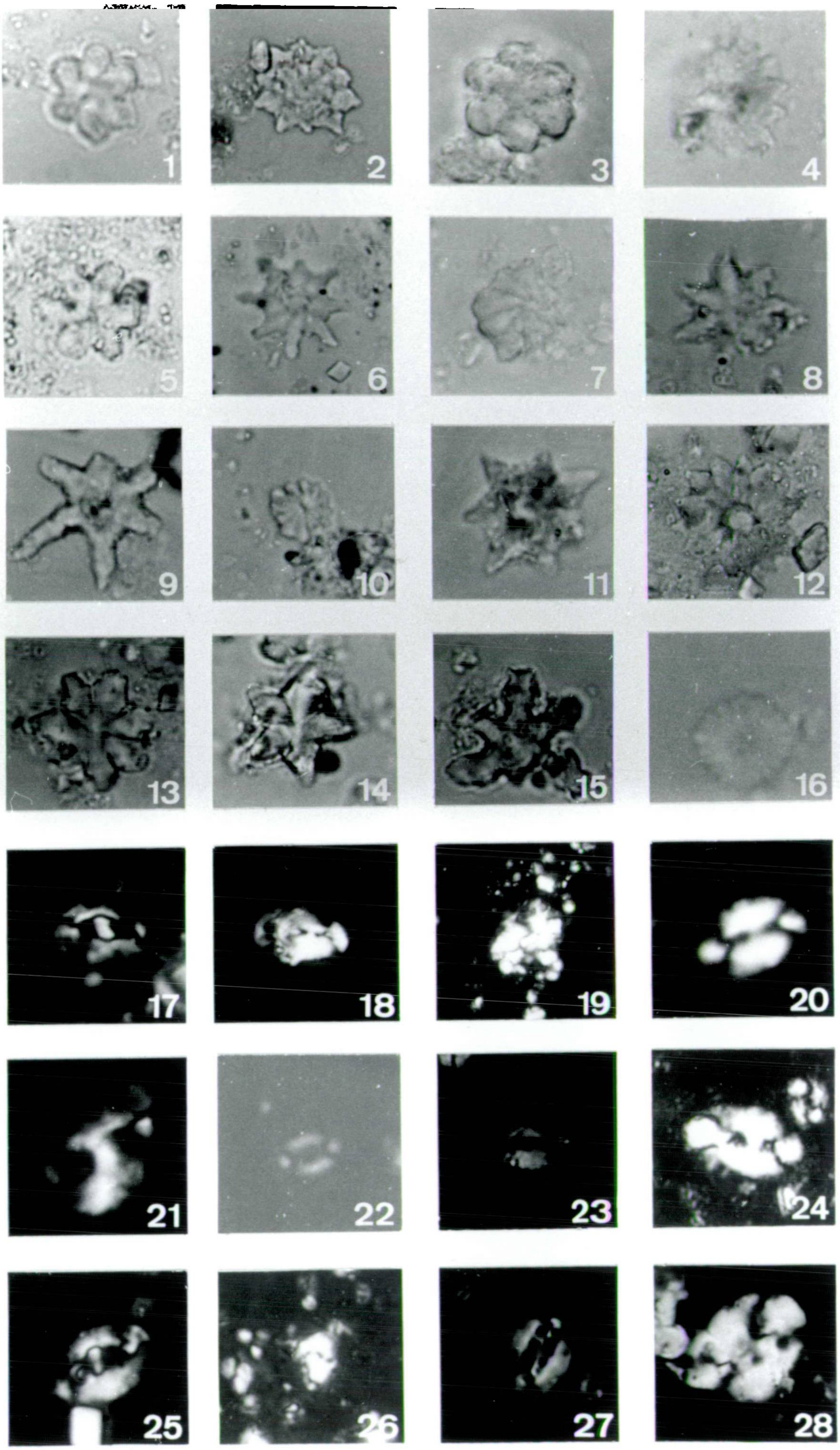

Plate No. 5

Sphenolithaceae,

Rhabdosphaeraceae,

Calciosoleniaceae &

Calyptrosphaeraceae.

PLATE No. 5

Sphenolithaceae Deflandre (1952):

1. ***Sphenolithus anarrhopus***. (a) and (b) Side view at 90° and 45° in XPL respectively. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3487/ 1 and 2.
2. ***Sphenolithus ciperoensis***. (a) and (b) Side view at 90° and 45° in XPL respectively. Mid Miocene (R), Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 21 & 22.
3. ***Sphenolithus conicus***. (a) and (b) Side view at 90° and 45° in XPL respectively. Mid Miocene, Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 27 and 28.
4. ***Sphenolithus dissimilis***. (a) and (b) Side view at 90° and 45° in XPL respectively. Zone IT2, Late Oligocene, Pulkhana No. 5, Serikagni Formation, Sample No. Pu-5/ 1, UCL 3491/ 17 and 18.
5. ***Sphenolithus editus***. Side view at 90° in XPL. Zone IT8a, Early Eocene, Chemchemal No. 2, Sinjar Limestone Formation, Sample No. Ch-2/ 52, UCL 3598/ 10.
6. ***Sphenolithus elongatus***. Side view at 90° in XPL. Zone IT8c, Early Eocene (C), Kirkuk No. 116, Kolosh Clastics Formation, Sample No. K-116/ 1, UCL 3617/ 8.
7. ***Sphenolithus heteromorphus***. (a) and (b) Side view at 90° and 45° in XPL respectively. Mid Miocene, Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 30 and 31.
8. ***Sphenolithus moriformis***. (a) and (b) Side view at 90° and 45° in XPL respectively. Mid Miocene (R), Jambur No. 4, Lower Fars Formation (Transition Beds), Sample No. Ja-4/ 1, UCL 3751/ 11 & 12.
9. ***Sphenolithus moriformis* Group**. (a) and (b) Side view at 90° and 45° in XPL respectively. Zone IT7, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 33, UCL 3254/ 20 and 21.
10. ***Sphenolithus radians***. (a) and (b) Side view at 90° and 45° in XPL respectively. Zone IT8a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formation, Sample No. Ch-2 / 52, UCL 3598/ 15 and 16.
11. ***Sphenolithus spiniger***. (a) and (b) Side view at 90° and 45° in XPL respectively. Zone IT5, Early Oligocene (R), Kirkuk No. 85, Palani Formation, Sample No. K-85/ 15, UCL 3698/ 4 and 5.

Rhabdosphaeraceae Lemmermann (1908):

12. ***Rhabdolithus* sp.** Side view at 90° in XPL. Zone IT7, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 33, UCL 3254/ 26.
13. ***Rhabdolithus solus***. Side view at 90° in XPL. Zone IT9a, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Ch-2/ 92, UCL 3645/ 12.
14. ***Rhabdolithus tenuis***. Side views at 90° in XPL. Zone IT5, Early Oligocene, Kirkuk No. 85, Palani Formation, Sample No. K-85/ 19, UCL 3271/ 32.
15. ***Rhabdolithus truncata***. Side view at 90° in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 104.

Calciosoleniaceae Kamptner (1927):

16. ***Scapholithus rhombiformis***. Distal view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 7, UCL 3587/ 5.

Calyptrosphaeraceae Boudreaux & Hay (1969):

17. ***Zygrhablithus bijugatus***. (a) Dital view at 90° in XPL (b) Side view at 90° in XPL. Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, (c) Side view at 90° in XPL. Zone IT9a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 73, UCL 3246/ 23, UCL 3271/ 18 and UCL 3599/ 28 respectively.

PLATE 5

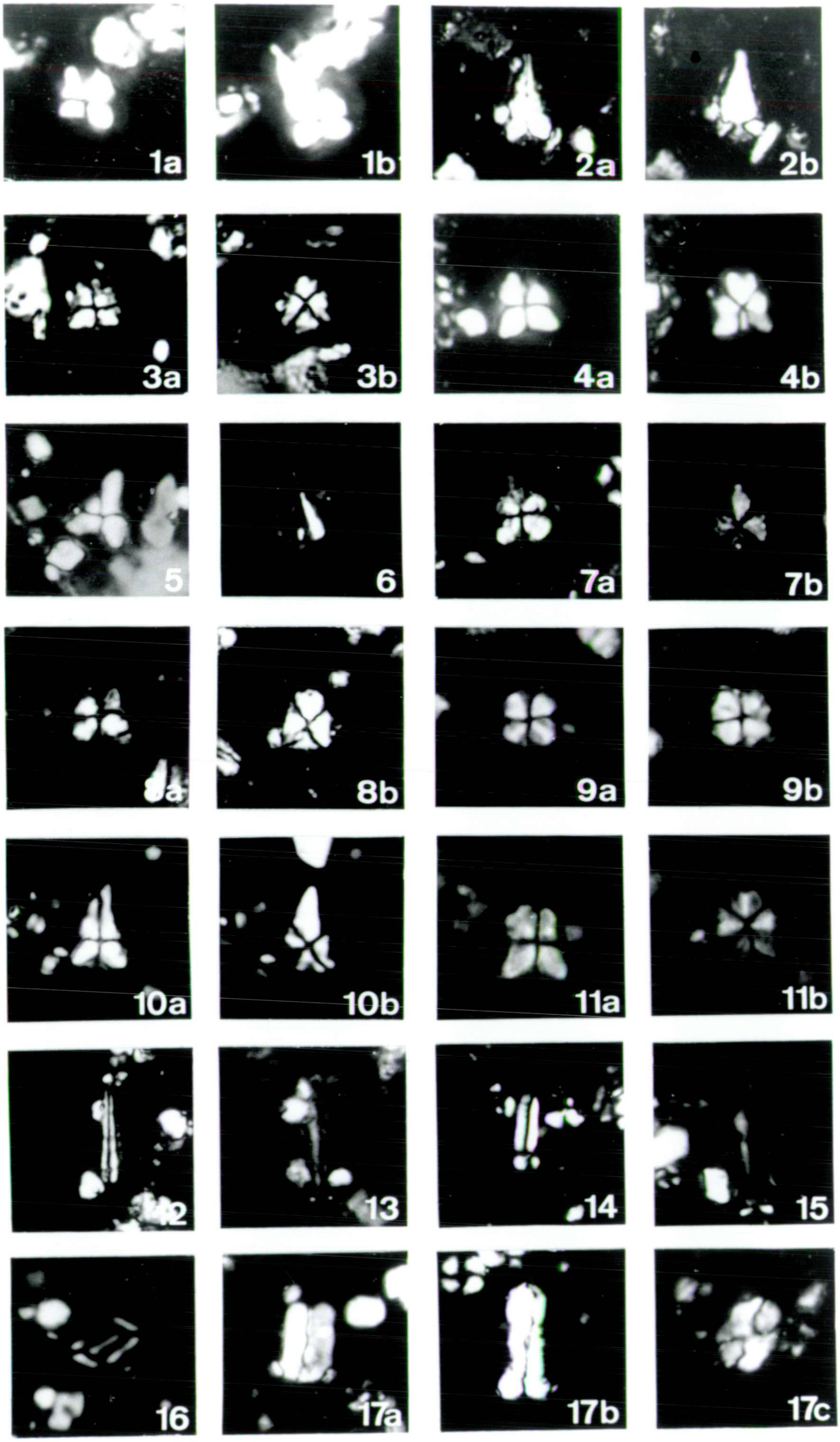
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Plate No. 6

Coccolithaceae,

Noelaerhabdaceae

& Fasciculithaceae.

Coccolithaceae Poche (1913):

1. ***Calcidiscus macintyrei.*** Distal view in XPL. Zone IT3, Late Oligocene (C), Bai Hassan No. 10, Ibrahim Formation, Sample No. BH-10/ 40, UCL 3610/ 9.
2. ***Campylosphaera eodela.*** Distal view in XPL. Zone IT9b, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 91, UCL 3601/ 9.
3. ***Chiasmolithus bidens.*** Distal view in XPL. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3488/ 14.
4. ***Chiasmolithus consuetus.*** Distal view in XPL. Zone IT9a, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 78, UCL 3645/ 4.
5. ***Coccolithus pelagicus.*** Distal view in XPL. Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, UCL 3271/ 19.
6. ***Cruciplacolithus latipons.*** Distal view in XPL. Zone IT9c, Early Eocene (R), Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 101, UCL 3645/ 19.
7. ***Cruciplacolithus tenuis.*** Distal view in XPL. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Sample No. Pu-5/ 39, UCL 3488/ 12.
8. ***Ericsonia formosa.*** Distal view in XPL. Zone IT9c, Early Eocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Sample No. Ch-2/ 103, UCL 3601/ 33.
9. ***Ericsonia obrupta.*** Distal view in XPL. Zone IT9a, Early Eocene (C), Chemchemal No. 2, Aaliji/ Kolosh Clastics Foramtion, Sample No. Ch-2/ 73, UCL 3599/ 5.
10. ***Ericsonia robusta.*** Distal view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Foramtion, Sample No. K-116/ 9, UCL 3586/ 26.
11. ***Markalius inversus.*** Distal view in XPL. Zone IT10, Late Palaeocene, Kirkuk No. 116, Aaliji Foramtion, Sample No. K-116/ 17, UCL 3617/ 21.
12. ***Pyrocyclus hermosus.*** Distal view in XPL. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3698/ 22.

Noelaerhabdaceae Jerkovič (1970):

13. ***Cyclicargolithus floridanus.*** Distal view in XPL. Mid Miocene (R), Chemchemal No. 2, Lower Fars Formation (Transition Beds), Sample No. Ch-2/ 1, UCL 3598/ 2.
14. ***Prinsius bisulcus.*** Distal view in XPL. Zone IT10, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, K-116/ 14., UCL 3587/ 14.
15. ***Prinsius martinii.*** Distal view in XPL. Zone IT11, Mid to Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Pu-5/ 40, UCL 3487/ 22.
16. ***Reticulofenestra minuta.*** Distal view in XPL. Mid Miocene (R), Rachi No. 1, Abu Ghar Formation, Sample No. Ra-1/ 4, UCL 3681/ 16.
17. ***Reticulofenestra scrippsae.*** Distal view in XPL. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Pu-5/ 26, UCL 3489/ 3.
18. ***Reticulofenestra umbilica.*** Distal view in XPL. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 26, UCL 3489/ 20.
19. ***Toweius eminens.*** Distal view in XPL. Zone IT11, Mid Palaeocene to Early Eocene, Pulkhana No. 5, Aaliji Formation, Pu-5/ 40, UCL 3493/ 26.
20. ***Toweius tovae.*** Distal view in XPL. Zone IT10, Late Palaeocene, Pulkhana No. 5, Aaliji Formation, Pu-5/ 39, UCL 3487/ 3.

Fasciculithaceae Hay & Mohler (1967):

21. ***Fasciculithus* sp. 1.** Side view in XPL. Zone IT10a, Late Palaeocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Ch-2/ 109, UCL 3645/ 29.
22. ***Fasciculithus alanii.*** Side view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, K-116/ 7, UCL 3578/ 29.
23. ***Fasciculithus bitectus.*** Side view in XPL. Zone IT10, Late Palaeocene (R), Kirkuk No. 116, Aaliji Formation, K-116/ 14, UCL 3578/ 18.
24. ***Fasciculithus bobii.*** Side view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, K-116/ 12, UCL 3270/ 27.
25. ***Fasciculithus involutus.*** Side view in XPL. Zone IT10a, Late Palaeocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Ch-2/ 109, UCL 3602/ 34.
26. ***Fasciculithus janii.*** Side view in XPL. Zone IT12, Mid Palaeocene, Kirkuk No. 116, Aaliji Formations, K-116/ 22, UCL 3587/ 23.
27. ***Fasciculithus richardii.*** Side view in XPL. Zone IT10a, Late Palaeocene, Kirkuk No. 116, Aaliji Formations, K-116/ 7, UCL 3587/ 31.
28. ***Fasciculithus thomasii.*** Side view in XPL. Zone IT10a, Late Palaeocene, Chemchemal No. 2, Aaliji/ Kolosh Clastics Formations, Ch-2/ 109, UCL 3602/ 27.

PLATE 6

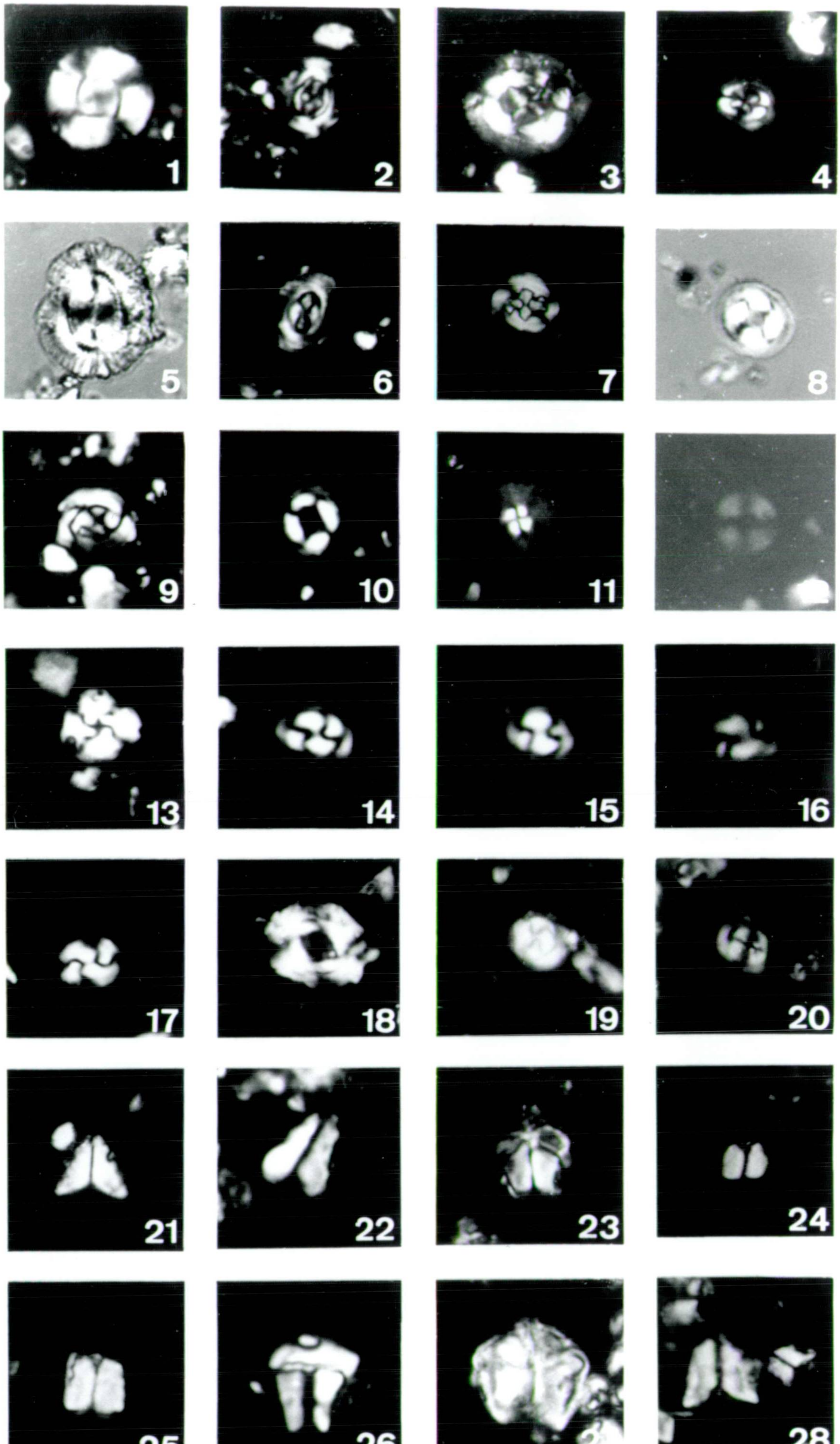


Plate No. 7

Scanning Electron Micrographs.

PLATE No. 7

The white scale bar on all the scanning electron micrographs are equivalent to 1 μm. .

1. General view of a typical SEM stub showing heavily overgrown coccoliths. Zone IT5, Early Oligocene, M.P.C. Well Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3933/ 13.

2. ***Coccolithus pelagicus***. (a), (b) and (c) Distal views exhibiting increasing amonts of secondary calcite overgrowth:
(a) Zone IT6, Mid Eocene, Kirkuk No. 85, Jaddala Formation, Sample No. K-85/ 27, UCL 3252/ 26.
(b) Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3936/ 5.
(c) Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 33, UCL 3615/ 10.

3. ***Discoaster barbadiensis***. Distal view exhibiting slight secondary calcite overgrowth. Zone IT7, Mid Eocene, Pulkhana No. 5, Jaddala Formation, Sample No. Pu-5/ 33, UCL 3615/ 9.

4. ***Discoaster* cf. *D. mohleri***. Distal view exhibiting moderate secondary calcite overgrowth within its central area. Zone IT10, Late Palaeocene, Kirkuk No. 116, Aaliji Formation, Sample No. K-116/ 12, UCL 3275/ 16.

5. ***Discoaster* sp.** . Distal view of a heavily overgrown specimen. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3933/ 7.

6. ***Helicosphaera compacta***. Distal view exhibiting only slight secondary calcite overgrowth. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1// 14, UCL 3933/ 20.

7. ***Helicosphaera euphratis***. Distal view with moderate secondary calcite overgrowth. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3933/ 18.

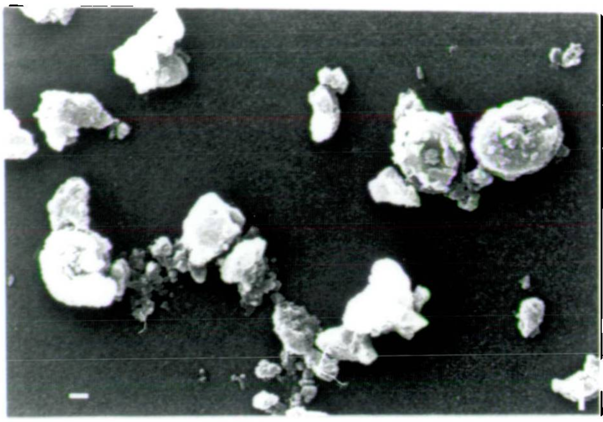
8. ***Helicosphaera* sp.** . Distal view heavily overgrown with secondary calcite overgrowth. Zone IT5, Early Oligocene, Kirkuk No. 85, Palani Formation, Sample No. K-85/ 19, UCL 3275/ 17.

9. ***Cyclicargolithus floridanus***. Distal view exhibiting virtually no secondary calcite overgrowths. Zone IT5, Early Oligocene, Kirkuk No. 85, Palani Formation, Sample No. K-85/ 19, UCL 3252/ 12.

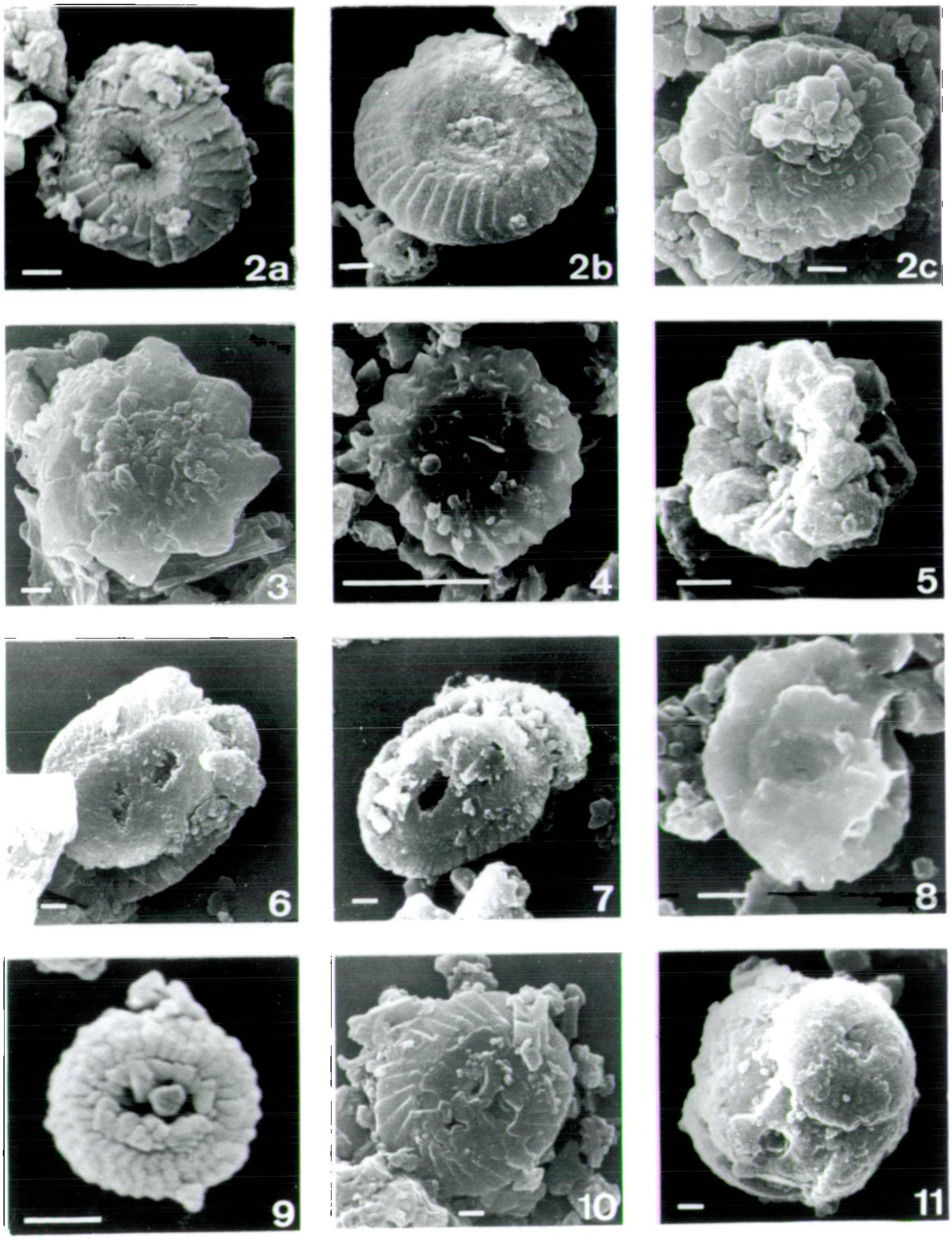
10. ***Watznaueria* cf. *W. barnesae***. Distal view exhibiting moderate secondary calcite overgrowth around its central area. Zone IT13, Late Maastrichtian, Chemchemal No. 2, Tanjero Clastics Formation, Sample No. Ch-2/ 134, UCL 3615/ 1.

11. **Coccosphere**. Heavily overgrown with secondary calcite. Zone IT5, Early Oligocene, Musaiyib No. 1, Palani Formation, Sample No. Mu-1/ 14, UCL 3936/ 6.

PLATE 7



INCREASING AMOUNTS OF SECONDARY CALCITE OVERGROWTH



CHAPTER SIX
BIOSTRATIGRAPHY

6.1 Introduction.

The calcareous nannofossil zonation scheme developed during this study is based upon the examination of 515 samples selected from 10 wells drilled in northern, central and southern Iraq. The samples studied include drill cuttings, conventional core and bit samples.

When the wells were originally drilled the conventional core material that was collected was not diagnostically labeled. In addition to this, the majority of the samples available for this study are drill cuttings. These constraints mean that only the first down hole occurrences (FDO's) of taxa can be reliably used to establish a zonation scheme. The 10 wells selected from northern, central and southern Iraq sample the Lower Fars (Transition Beds and Basal Conglomerate), Abu Ghar, Jeribe Limestone, Dhiban Anhydrite, Euphrates Limestone, Serikagni, Anah Limestone, Azkand Limestone, Ibrahim, Bajawan Limestone, Baba Limestone, Tarjil, Shurau Limestone, Sheik Alas Limestone, Palani, Dammam Limestone, Jaddala, Avanah Limestone, Pila Spi Limestone, Gercüş Red Beds, Umm Er Radhuma, Aaliji, Sinjar Limestone, Khurmala Limestone, Kolosh Clastics, Tayarat Limestone, Pilsner Limestone, Shiranish Limestone and the Tanjero Clastics Formations.

6.2 Systematic Biostratigraphy.

As a result of this study 13 zones and 7 subzones have been established for the study area based upon the first downhole occurrences (F.D.O's) and acme occurrences of taxa (see Figure 6.1). The marker species used to establish the zonation scheme presented below, were selected using the general biostratigraphic guidelines outlined in the Methodology Chapter 4.0:

(1) Marker species must have distinctive first or last occurrences that can be recognised in many sections.

(2) Marker species must be easily identifiable in the light microscope.

(3) Marker species should be a reasonably common constituent of the total nannofossil assemblage.

(4) Marker species should be geographically widespread and preferably have a cosmopolitan nature.

6.0 Biostratigraphy

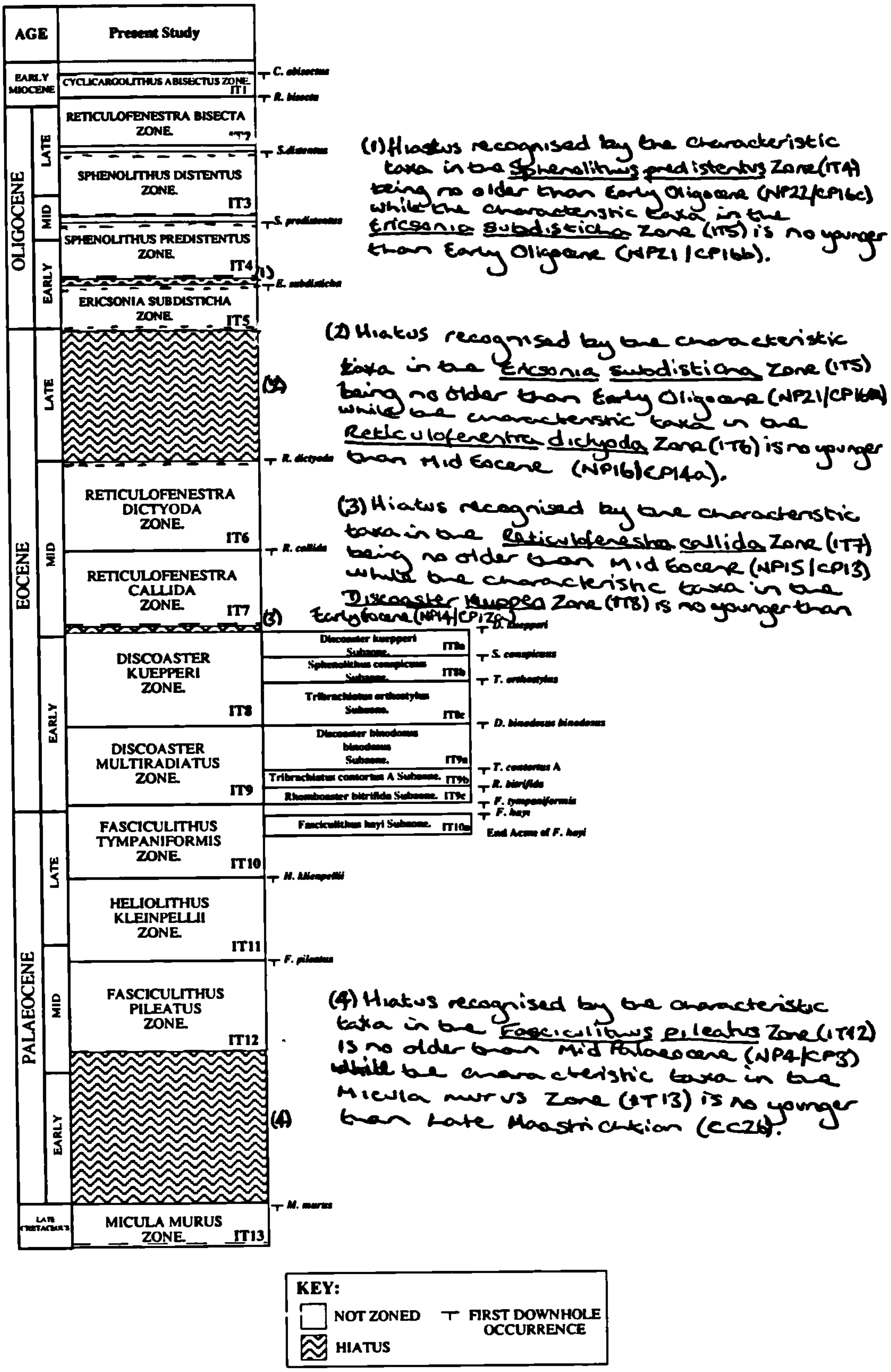


Figure 6.1 The Calcareous Nannofossil Zonation Scheme Developed During This Present Study.

6.0 Biostratigraphy

The numbering system adopted here provides a short hand method of referring to the zones and subzones in this zonation scheme. The notation used for the zones and subzones stands for Iraq Tertiary (IT), and are numbered following their first downhole occurrences. The subzones within a zone are labeled a,b, or c again following their first downhole occurrences within a zone. The zones and subzones established in this study are listed and systematically described in descending stratigraphic order below:

6.2.1 *Cyclicargolithus abisectus* Zone (IT1).
6.2.2 *Reticulofenestra bisecta* Zone (IT2).
6.2.3 *Sphenolithus distentus* Zone (IT3).
6.2.4 *Sphenolithus predistentus* Zone (IT4).
6.2.5 *Ericsonia subdisticha* Zone (IT5).
6.2.6 *Reticulofenestra dictyoda* Zone (IT6).
6.2.7 *Reticulofenestra callida* Zone (IT7).
6.2.8 *Discoaster kuepperi* Zone (IT8):
- **6.2.8(i) *Discoaster kuepperi* Subzone (IT8a).**
- **6.2.8(ii) *Sphenolithus conspicuus* Subzone (IT8b).**
- **6.2.8(iii) *Tribrachiatus orthostylus* Subzone (IT8c).**

6.2.9 *Discoaster multiradiatus* Zone (IT9):
- **6.2.9(i) *Discoaster binodosus binodosus* (IT9a).**
- **6.2.9(ii) *Tribrachiatus contortus* Subzone (IT9b).**
- **6.2.9(iii) *Rhomboaster bitrifida* Subzone (IT9c).**

6.2.10 *Fasciculithus tympaniformis* Zone (IT10):
- **6.2.10(i) *Fasciculithus hayi* Subzone (IT10a).**

6.2.11 *Heliolithus kleinpellii* Zone (IT11).
6.2.12 *Fasciculithus pileatus* Zone (IT12).
6.2.13 *Micula murus* Zone (IT13).

6.2.1 CYCLICARGOLITHUS ABISECTUS Zone (IT1).

Definition: from FDO *Cyclicargolithus abisectus*

Category: Partial Range Zone.

Age: Early Miocene.

Occurrence: Jambur No. 4 (Serikagni Formation, 7240' - 7270').

Assemblage: *Coccolithus pelagicus*, *Cyclicargolithus abisectus*, *C. floridanus*, *Helicosphaera scissura* and *Sphenolithus moriformis* Group.

Chronostratigraphic Significance: This zone is equivalent to the lower part of the *Triquetrorhabdulus carinatus* Zone (NN1) of Martini (1971) and is also equivalent to the upper part of the Cyclicargolithus abisectus Subzone (CN1a) of Okada and Bukry (1980).

6.2.2 RETICULOFENESTRA BISECTA Zone (IT2).

Definition: From FDO of *Reticulofenestra bisecta*.

Category: Partial Range Zone.

Age: Late Oligocene to Early Miocene (base not seen).

Occurrence: Jambur No. 4 (Serikagni Formation, 7299' - 7415') and Pulkhana No. 5 (Serikagni Formation, 4075'- 4085').

Assemblage: Same as the *Cyclicargolithus abisectus* Zone (IT1) with the addition of *Braarudosphaera bigelowii, Discoaster deflandrei, Helicosphaera euphratis, Pontosphaera* spp., *Reticulofenestra bisecta, R. minuta, R. scrippsae, Sphenolithus dissimilis, S. moriformis* Group, and *Zygrhablithus bijugatus*, and the exclusion of *Helicosphaera scissura.*

Chronostratigraphic Significance: This zone is equivalent to the *Sphenolithus ciperoensis* Zone (NP25) and the lower part of the *Triquetrorhabdulus carinatus* Zone (NN1) of Martini (1971) and is also equivalent to the *Dictyococcites bisectus* Subzone (CP19b) and the lower part of the *Cyclicargolithus abisectus* Subzone (CN1a) of Okada and Bukry (1980).

6.2.3 SPHENOLITHUS DISTENTUS Zone (IT3).

Definition: FDO *Sphenolithus distentus* (Base not seen).

Category: Total Range Zone.

Age: Late Oligocene.

Occurrence: Bai Hassan No. 10 (Ibrahim Formation, 4310' - 4425').

Assemblage: Same as the *Reticulofenestra bisecta* Zone (IT2) with the addition of *Discoaster adamanteus, Reticulofenestra haqii, Sphenolithus distentus*, and the exclusion of *Braarudosphaera bigelowii* and *Sphenolithus dissimilis.*

Chronostratigraphic Significance: This zone is equivalent to the *Sphenolithus distentus* Zone (NP24) of Martini (1971) and is also equivalent to the *Cyclicargolithus floridanus* Subzone (CP19a) of Okada and Bukry (1980).

6.2.4 SPHENOLITHUS PREDISTENTUS Zone (IT4).

Definition: FDO *Sphenolithus predistentus*

Category: Partial Range Zone.

Age: Mid to Early Oligocene. (Base not seen).

Occurrence: Bai Hassan No. 8 (Tarjil Formation, 4945' - 4972') and Kirkuk No. 85 (Tarjil Formation, 2995' - 3190').

Assemblage: Same as the *Sphenolithus distentus* Zone (IT3) with the addition of *Ericsonia obrupta*, *Rhabdolithus* spp., *Reticulofenestra umbilica*, *Sphenolithus predistentus*, but excluding *Cyclicargolithus abisectus*, *Discoaster adamanteus*, *D. deflandrei*, *Sphenolithus distentus*, *Reticulofenestra haqii*, and *R. minuta*.

Chronostratigraphic Significance: This zone is probably equivalent to the *Helicosphaera reticulata* Zone (NP22) and the lower part of *Sphenolithus predistentus* Zone (NP23) of Martini (1971) and the *Reticulofenestra hillae* Subzone (CP16c) *and Sphenolithus predistentus* Zone (CP17) of Okada and Bukry (1980) based upon the occurrence of *Reticulofenestra umbilica* with *Sphenolithus predistentus* however, due to the poorly preserved nature of the zone in this study it is hard to define accurately.

6.2.5 ERICSONIA SUBDISTICHA Zone (IT5).

Definition: FDO *Ericsonia subdisticha*

Category: Partial Range Zone.

Age: Early Oligocene. (Base not seen).

Occurrence: Jambur No. 4 (Jaddala Formation, 7415' - 7445'), Kirkuk No. 85 (Palani Formation 3190' - 3395'), Musaiyib No. 1 (Palani Formation, 2820' - 3240') and Pulkhana No. 5 (Jaddala, 4085' - 4441').

Assemblage: Same as the *Sphenolithus predistentus* Zone (IT4) with the addition of *Braarudosphaera bigelowii*, *Chiasmolithus titus*, *Discoaster tanii*, *D. tanii nodifer*, *Ericsonia formosa*, *E. subdisticha*, *Helicosphaera bramlettei*, *H. compacta*, *H. minima*, *Micrantholithus flos*, *Pontosphaera multipora*, *Pyrocyclus hermosus*, *Reticulofenestra hillae*, *R. minuta*, *R. umbilica*, *Rhabdolithus tenuis*, *Sphenolithus moriformis*, *S. radians*, and *Traversopontis obliquipons*.

Pyrocyclus hermosus is a particularly useful species as it consistently appears exclusively within this zone.

Chronostratigraphic Significance: This zone is equivalent to the *Ericsonia subdisticha* Zone (NP21) of Martini (1971) and is also equivalent to the *Coccolithus subdistichus* Subzone (CP16b) and the *Coccolithus formosus* Subzone (CP16a) of Okada and Bukry (1980).

6.2.6 RETICULOFENESTRA DICTYODA Zone (IT6).

Definition: FDO *Reticulofenestra dictyoda*

Category: Partial Range Zone.

Age: Mid Eocene.

Occurrence: Atshan No.1 (Avanah Limestone/ Jaddala Formation, 445' - 636'), Kirkuk No. 85 (Jaddala Formation, 3395' - 3510'), Musaiyib No. 1 (Jaddala Formation, 3240' - 3245') and Pulkhana No. 5 (Jaddala Formation, 4441' - 4770') Rachi No. 1 (Dammam Limestone and Rus Anhydrite Formations, 1640' - 2090').

Assemblage: Same as the *Ericsonia subdisticha* Zone (IT5) with the addition of *Chiasmolithus consuetus, C. grandis, C. solitus, Discoaster barbadiensis, D. deflandrei, D. gemmeus, D. wemmelensis, Helicosphaera seminulum, Markalius inversus, Reticulofenestra dictyoda, Transversopontis rectipons*, but with the exclusion of *Chiasmolithus titus, Discoaster tanii, Helicosphaera bramlettei, H. compacta, H. minima, Micrantholithus flos, Pyrocyclus hermosus, Rhabdolithus tenuis,* and *Sphenolithus moriformis* Group.

Chronostratigraphic Significance: This zone is equivalent to the upper part of the *Discoaster tanii nodifer* Zone (NP16) of Martini (1971) and is also equivalent to the *upper part of the Discoaster bifax* Subzone (CP14a) of Okada and Bukry (1980).

6.2.7 RETICULOFENESTRA CALLIDA Zone (IT7).

Definition: FDO *Reticulofenestra callida*

Category: Partial Range Zone.

Age: Mid Eocene. (Base not seen)

Occurrence: Kirkuk No. 85 (Jaddala Formation, 3510' - 3665'), Pulkhana No. 5 (Jaddala Formation, 4770' - 5069') and Rachi No. 1 (Rus Anhydrite Formation, 2090'

- 2095').

Assemblage: Same as the *Reticulofenestra dictyoda* Zone (IT6) with the addition of *Discoaster saipanensis*, *Helicosphaera compacta*, *Nannotetrina fulgens*, *Reticulofenestra callida*, *Sphenolithus furcatolithoides*, *S. spiniger* but excluding *Chiasmolithus consuetus*, *C. grandis*, *C. solitus*, *Discoaster barbadiensis*, *D. deflandrei*, *D. gemmeus*, *D. wemmelensis*, *Helicosphaera euphratis*, *H. seminulum* and *Pontosphaera multipora*.

Chronostratigraphic Significance: This zone is equivalent to the lower part of the *Discoaster tanii nodifer* Zone (NP16) and the lower part of the *Discoaster bifax* Subzone (CP14a). This zone is also equivalent to the upper part of the *Nannotetrina fulgens* Zone (NP15) of Martini (1971) and the upper part of the *Nannotetrina quadrata* Zone (CP13) of Okada and Bukry (1980).

6.2.8 DISCOASTER KUEPPERI Zone (IT8).

Definition: FDO *Discoaster kuepperi*

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Sinjar Limestone, Aaliji/ Kolosh Clastics Formations, 2800' - 4690'). This zone also appears in Pulkhana No. 5 (Aaliji Formation, 5069' - 5130') where it is mixed in with the *Discoaster multiradiatus* Zone. The explanation of this zone in Pulkhana No. 5 is fully explained under the *Discoaster multiradiatus* Zone. The *Discoaster kuepperi* Zone can be subdivided into 3 subzones in Chemchemal No. 2 but, in Kirkuk No. 116 the *Discoaster kuepperi* Zone has not been fully sampled. However, the top of the Kirkuk No. 116 well section can be correlated to the *Tribrachiatus orthostylus* Subzone though the base of this subzone is hard to locate as *Discoaster multiradiatus* is reworked into the *Tribrachiatus orthostylus* Subzone.

The three subzones that can be established within the *Discoaster kuepperi* Zone are now explained in descending stratigraphic order:

6.2.8(i) Discoaster kuepperi Subzone (IT8a).

Definition: FDO *Discoaster kuepperi*

Category: Partial Range Zone

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 2800' - 3220').

Assemblage: *Braarudosphaera bigelowii, Chiasmolithus consuetus, Coccolithus pelagicus, Discoaster kuepperi, D. salisburgensis, Discoaster* cf. *D. stella, Ellipsolithus macellus, Ericsonia formosa, E. robusta, Markalius inversus, Micrantholithus flos, Pontosphaera* spp., *S. moriformis* Group, *S. predistentus, S. radians, Traversopontis pulcher* and *Zygrhablithus bijugatus.*

Chronostratigraphic Significance: This subzone is equivalent to the lower part of the *Discoaster sublodoensis* Zone (NP14) and the upper part of the *Discoaster lodoensis* Zone (NP13) of Martini (1971). This subzone is also equivalent to the *Discoaster kuepperi* Subzone (CP12a) and the uppermost part of the *Discoaster lodoensis* Zone (CP11) of Okada and Bukry (1980).

6.2.8(ii) Sphenolithus conspicuus Subzone (IT8b).

Definition: FDO *Sphenolithus conspicuus* .

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formation, 3220' - 3310').

Assemblage: Same as the *Discoaster kuepperi* Zone (IT8a) with the addition of *Discoaster barbadiensis, Lophodolithus nacens, Micrantholithus pinguis, Neococcolithes protenus, Sphenolithus conspicuus* and *S. editus* but without *Ellipsolithus macellus, Ericsonia robusta* and *Sphenolithus predistentus.*

Chronostratigraphic Significance: This subzone is equivalent to the lower most part of the *Discoaster lodoensis* Zone (NP13) of Martini (1971) and the lower most part *Discoaster lodoensis* Zone of Okada and Bukry (1980).

6.2.8(iii) Tribrachiatus orthostylus Subzone (IT8c).

Definition: FDO *Tribrachiatus orthostylus* to the FDO of *Discoaster multiradiatus.*

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 3310' - 4210') and Kirkuk No. 116 (Aaliji and Kolosh Clastics Formations, 4490' - 4535'). As stated earlier, the base of the *Tribrachiatus orthostylus* Subzone (IT8a) is difficult to locate in the Kirkuk No. 116 as *Discoaster multiradiatus* is reworked into this subzone.

Assemblage: Same as the *Sphenolithus conspicuus* Subzone (IT8b) with the addition of *Discoaster deflandrei, D. lodoensis, Ellipsolithus macellus,* Reticulofenestra dictyoda, *Sphenolithus elongatus*, S. furcatolithoides, *Tribrachiatus orthostylus* A and *T. orthostylus* B but, without *Lophodolithus nacens*.

Chronostratigraphic Significance: This subzone is equivalent to the *Tribrachiatus orthostylus* Zone (NP12) of Martini (1971) is also equivalent to the *Tribrachiatus orthostylus* Zone (CP10) of Okada and Bukry (1980).

6.2.9 DISCOASTER MULTIRADIATUS Zone (IT9).

Definition: FDO *Discoaster multiradiatus*

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastic Formations, 3730' - 4690'), Kirkuk No. 116 (Kolosh Clastics and Aaliji Formations, 4490' - 4550') and Pulkhana No. 5 (Aaliji Formation, 5069' - 5130'). The *Discoaster multiradiatus* Zone (IT9) can be split up into three subzones in Chemchemal No. 2, but in Kirkuk No. 116 it is difficult to locate this zone as it is thin and *Discoaster multiradiatus* is reworked into the *Tribrachiatus orthostylus* Subzone (IT8c). In Kirkuk No. 116 the *Discoaster multiradiatus* Zone (IT9) has tentatively been assigned to the interval between 4535' and 4540'. In Pulkhana No. 5 the *Discoaster multiradiatus* Zone (IT9) is mixed in with the younger *Discoaster kuepperi* Zone (IT8) as this part of the section is condensed.

The characteristic taxa of the *Discoaster multiradiatus* Zone (IT9) in Kirkuk No. 116 is listed below:

Assemblage: *Braarudosphaera bigelowii, Chiasmolithus consuetus, Coccolithus pelagicus, Discoaster barbadiensis, D. kuepperi, D. salisburgensis, Discoaster* cf. *D. stella, Ellipsolithus macellus, Ericsonia formosa, E. robusta, Lophodolithus nacens, Markalius inversus, Micrantholithus flos, M. pinguis, Neococcolithes protenus, Pontosphaera* spp., *Sphenolithus conspicuus, S. editus, S. moriformis* Group, *S. predistentus, S. radians, Traversopontis pulcher* and *Zygrhablithus bijugatus.*
Chronostratigraphic Significance: This zone is equivalent to the Discoaster binodosus Zone (NP11) and the Tribrachiatus contortus (NP10) of Martini (1971) and the *Discoaster binodosus* Subzone (CP9b) and the *Tribrachiatus contortus* Subzone of Okada and Bukry (1980).

The characteristic taxa of Pulkhana No. 5 which comprises a mixed interval of two zones (*Discoaster kuepperi* Zone and *Discoaster multiradiatus* Zone) are listed below:

Characteristic Taxa: *Braarudosphaera bigelowii, Campylosphaera eodela, Chiasmolithus bidens, C. consuetus, Coccolithus pelagicus, Discoaster barbadiensis, D. deflandrei, D. kuepperi, D. lodoensis, D. multiradiatus, D. nobilis, D. salisburgensis, Ericsonia formosa, Markalius inversus, Micrantholithus flos, Pontosphaera* spp., *Reticulofenestra dictyoda, Sphenolithus moriformis* Group, *S. radians, Toweius eminens, Tribrachiatus orthostylus* B, and *Zygrhablithus bijugatus.*
Chronostratigraphic Significance: These two zones are equivalent to the lower part of the *Discoaster sublodoensis* Zone (NP14), *Discoaster lodoensis* Zone (NP13), the *Tribrachiatus orthostylus* Zone (NP12), the *Discoaster binodosus* Zone (NP11) and the *Tribrachiatus contortus* Zone (NP10) of Martini (1971). These two zones are also equivalent to the *Discoaster kuepperi* Subzone (CP12a), *Discoaster lodoensis* Zone (CP11), *Tribrachiatus orthostylus* Zone (CP10), *Discoaster binodosus* Subzone (CP9b) and the *Tribrachiatus contortus* (CP9a) of Okada and Bukry (1980).

The *Discoaster multiradiatus* Zone in the thicker, Chemchemal No. 2 can be sub-divided into to three subzones which are described below in descending stratigraphic order.

6.2.9(i) Discoaster binodosus binodosus Subzone (IT9a).

Definition: FDO of *Discoaster binodosus binodosus*

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 3730' - 4060').

Assemblage: *Braarudosphaera bigelowii, Campylosphaera eodela, Chiasmolithus bidens, C. consuetus, Coccolithus pelagicus, Discoaster barbadiensis, D. binodosus binodosus, D. falcatus, D. lodoensis, D. multiradiatus, D. salisburgensis, Discoaster* cf. D. *stella, Ellipsolithus macellus, Ericsonia robusta, Lophodolithus nacens, Markalius inversus, Micrantholithus flos, M. pinguis, Neochiastozygus distentus, N. junctus, Neococcolithes protenus, Pontosphaera* spp., *Sphenolithus anarrhopus, S. editus, S. moriformis* Group, *S. radians, Thoracosphaera operculata, Toweius eminens, Traversopontis pulcher, Tribrachiatus orthostylus* A, *T. orthostylus* B and *Zygrhablithus bijugatus.*

Chronostratigraphic Significance: This subzone is equivalent to the *Discoaster binodosus* Zone (NP11) and the uppermost part of the *Tribrachiatus contortus* Zone (NP10) of Martini (1971) and the *Discoaster binodosus* Subzone (CP9b) and the uppermost part of the *Tribrachiatus contortus* Subzone (CP9a) of Okada and Bukry (1980).

6.2.9(ii) Tribrachiatus contortus A Subzone (IT9b).

Definition: FDO of *Tribrachiatus contortus* A

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 4060' - 4240').

Assemblage: Same as the Discoaster binodosus binodosus Zone (IT9a) including *Neochiastozygus chiastus, Rhabdolithus solus* and *Tribrachiatus contortus* A but excluding *Tribrachiatus orthostylus* B.

Chronostratigraphic Significance: This subzone is equivalent to the middle part of the *Tribrachiatus contortus* Zone (NP10) of Martini (1971) and the middle part of the

Tribrachiatus contortus Subzone (CP9a) of Okada and Bukry (1980). The evolution of slightly bifurcated forms of *Tribrachiatus orthostylus* from *Tribrachiatus contortus* occurs near the NP10 (CP9a)/ NP11 (CP9b) and was first recognised by Hekel (1968) and later by Romein (1979). This same evolutionary pattern has been recognised in the Chemchemal No. 2 well section and occurs at 4610 feet.

6.2.9(iii) Rhomboaster bitrifida Subzone (IT9c).

Definition: FDO *Rhomboaster bitrifida*

Category: Partial Range Zone.

Age: Early Eocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formation, 4240' - 4690').

Assemblage: Same as Tribrachiatus contortus A Subzone (IT9b) including *Rhomboaster bitrifida* but excluding *Neochiastozygus chiastus*, *Tribrachiatus orthostylus* A and *T. orthostylus* B.

Chronostratigraphic Significance: This subzone is equivalent to the lower part of the *Tribrachiatus contortus* Zone (NP10) of Martini (1971), and the lower part of the *Tribrachiatus contortus* Subzone (CP9a) of Okada and Bukry (1980).

6.2.10 FASCICULITHUS TYMPANIFORMIS Zone (IT10).

Definition: FDO *Fasciculithus tympaniformis*

Category: Partial Range Zone.

Age: Late Palaeocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 4690' - 5230'), Kirkuk No. 116 (Aaliji Formation, 4535' - 4675') and Pulkhana No. 5 (Aaliji Formation, 5130' - 5223').

Assemblage: *Braarudosphaera bigelowii*, *Campylosphaera eodela*, *Chiasmolithus bidens*, *C. consuetus*, *Coccolithus pelagicus*, *Cruciplacolithus latipons*, *C. tenuis*, *Discoaster binodosus binodosus*, *D. mohleri*, *D. multiradiatus*, *D. nobilis*, *D. salisburgensis*, *Ellipsolithus distichus*, *E. macellus*, *Ericsonia robusta*, *Fasciculithus* sp. 1, *F. bobii*, *F. hayi*, *F. alanii*, *F. richardii*, *F. schaubii*, *F. thomasii*, *F. tympaniformis*, *Lophodolithus nacens*, *Markalius inversus*, *Neochiastozygus distentus*, *N. junctus*, *Neococcolithes protenus*, *Placozygus sigmoides*, *Pontosphaera* spp., *Prinsius bisulcus*, *Rhomboaster bitrifida*, *Scapholithus rhombiformis*, *Sphenolithus anarrhopus*, *S. moriformis* Group, *Thoracosphaera operculata*, *Toweius eminens*, *T. pertusus*, *T. tovae* and *Zygodiscus bramlettei* and *Zygrhablithus bijugatus*.

Chronostratigraphic Significance: This zone is equivalent to the lowermost part of the *Tribrachiatus contortus* Zone (NP8) and the *Discoaster multiradiatus* Zone (NP9) of Martini (1971) and the lowermost part of the *Tribrachiatus contortus* Subzone (CP9a) and the *Discoaster multiradiatus* Zone (CP8), comprising *Campylosphaera eodela* Subzone (CP8b) and the *Chiasmolithus bidens* Subzone (CP8a) of Okada and Bukry (1980). The *Fasciculithus tympaniformis* Zone (IT10) is also equivalent to the *Fasciculithus involutus* Zone (NTp20), *Fasciculithus hayi* Zone (NTp19), *Fasciculithus lillianae* Zone (NTp18), *Placozygus sigmoides* Zone (NTp17) and the *Heliolithus cantabriae* Zone (NTp16), comprising the *Discoaster lenticularis* Subzone (NTp16B) and the *Heliolithus aktasii* Subzone (NTp16A) of Varol (1989).

The *Fasciculithus tympaniformis* Zone (IT10) may be split up further in Chemchemal No. 2 and Kirkuk No. 116 based on the acme of *Fasciculithus hayi*.

6.2.10(i) Fasciculithus hayi Subzone (IT10a).

Definition: FDO *Fasciculithus hayi* to the end of the acme of *Fasciculithus hayi*.

Category: Acme Zone.

Age: Late Palaeocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formation, 4720' - 4930') and Kirkuk No. 116 (Aaliji Formation, 4550' - 4595').

Assemblage: Same as the Fasciculithus tympaniformis Zone (IT10) but *Fasciculithus alanii*, *F. thomasii* and *F. tympaniformis* all have their acme occurrences in this subzone, and *Fasciculithus* sp. 1, *F. alanii*, *F. bobii*, *F. hayi*, *F. richardii*, and F. thomasii consistently and exclusively appear within this subzone.

Chronostratigraphic Significance: This subzone is equivalent to the lower part of the *Discoaster multiradiatus* Zone (NP9) of Martini (1971). The *Fasciculithus hayi* subzone is also equivalent to the lower part of the *Campylosphaera eodela* (CP8b) and the *Chiasmolithus bidens* (CP8a) of the *Discoaster multiradiatus* Zone (CP8) of Okada and Bukry (1980). The *Fasciculithus hayi* Subzone (IT10a) is also equivalent to the *Fasciculithus hayi* Zone (NTp19), *Fasciculithus lillianae* Zone (NTp18), *Placozygus sigmoides* Zone (NTp17) and the uppermost part of *Heliolithus cantabriae* Zone (NTp16) of Varol (1989).

6.2.11 HELIOLITHUS KLEINPELLII Zone (IT11).

Definition: FDO *Heliolithus kleinpellii*

Category: Total Range Zone.

Age: Mid to Late Palaeocene.

Occurrence: Chemchemal No. 2 (Aaliji/ Kolosh Clastics Formations, 5230' - 5410'), Kirkuk No. 116 (Aaliji, 4675' - 4715') and the Pulkhana No. 5 (Aaliji Formation, 5223' - 5280').

Assemblage: Same as the *Fasciculithus tympaniformis* Zone (IT10) with the addition of *Heliolithus kleinpellii, Neochiastozygus denticulatus, N. perfectus,* and *Prinsius martini,* but excluding *Campylosphaera eodela, Cruciplacolithus latipons, Discoaster binodosus binodosus, D. multiradiatus, D. nobilis, D. salisburgensis, Ericsonia robusta, Fasciculithus sp. 1, F. alanii, F. bobii, F. hayi, F. richardii, F. schaubii, F. thomasii, Lophodolithus nacens, Neochiastozygus distentus,* and *Zygrhablithus bijugatus.*

Chronstratigraphic Significance: This zone is equivalent to the base of the *Discoaster multiradiatus* Zone (NP9), the *Heliolithus riedelii/ Discoaster nobilis* (NP8), the *Discoaster mohleri* (NP7) and the upper part of the *Heliolithus kleinpellii* Zone (NP6) of Martini (1971). The *Heliolithus kleinpellii* Zone is also equivalent to the base of the *Discoaster multiradiatus* Zone (CP8), *Discoaster nobilis Zone (CP7), Discoaster mohleri* Zone (CP6) and the upper part of the *Heliolithus kleinpellii* Zone (CP5) of Okada and Bukry (1980). The *Heliolithus kleinpellii* Zone (IT11) is also equivalent to the *Hornibrookina australis* Zone (NTp15), *Munarinus emeri* Zone (NTp14), *Zygodiscus clausus* Zone (NTp13), *Discoaster drieveri* Zone (NTp12) and the *Fasciculithus billii* Zone (NTp11), comprising the *Sphenolithus anarrhopus* Subzone (NTp11B) and the *Zygodiscus herlynii* (NTp11A) of Varol (1989).

6.2.12 FASCICULITHUS PILEATUS Zone (IT12).

Definition: FDO *Fasciculithus pileatus*

Category: Partial Range Zone.

Age: Mid Palaeocene (Base not seen).

Occurrence: Kirkuk No. 116 (Aaliji Formation, 4715' - 4780') and Pulkhana No. 5 (Aaliji Formation, 5280' - 5370'). In Chemchemal No. 2 the *Fasciculithus pileatus* Zone cannot be distinguished, but representatives of this zone are reworked into the zones above (*Fasciculithus bitectus*, *F. janii*, *F. ulii*, *Neochiastozygus perfectus* and *Prinsius dimorphosus*).

Assemblage: Same as the *Heliolithus kleinpellii* Zone (IT12) with the addition of *Ericsonia robusta*, *Fasciculithus bitectus*, *Fasciculithus janii*, *Fasciculithus pileatus*, *Neochiastozygus modestus*, but with the exclusion of *Braarudosphaera bigelowii*, *Discoaster mohleri*, *Ellipsolithus distichus*, *E. macellus*, *Heliolithus kleinpellii*, *Neochiastozygus denticulatus*, *N. junctus*, *N. perfectus*, *Placozygus sigmoides*, *Prinsius bisulcus*, *P. martini*, and *Toweius pertusus*.

Chronostratigraphic Significance: This zone is equivalent to the lower part of the *Heliolithus kleinpellii* Zone (NP6), the *Fasciculithus tympaniformis* Zone (NP5) and possibly the uppermost part the Ellipsolithus macellus (NP4) of Martini (1971). This zone is also equivalent to the lower part of the *Heliolithus kleinpellii* Zone (CP5), the *Fasciculithus tympaniformis* Zone (CP4) and the Ellipsolithus macellus Zone (CP3) of Okada and Bukry (1980). The *Fasciculithus pileatus* Zone (IT12) is also equivalent to the *Fasciculithus pileatus* Zone (NTp10) of Varol (1989). This zone comprises the *Chiasmolithus bidens* Subzone (NTp10C), *Cruciplacolithus latipons* (NT10B), *Multipartis ponticus* (NTp10A), the *Neochiastozygus saepes* Zone (NTp9) and the upper part of the *Cruciplacolithus subrotudus* Zone (NTp8), the *Fasiculithus janii* Subzone (NTp8C).

6.2.13 MICULA MURUS Zone (IT13).

Definition: FDO *Micula murus* (Base not seen).

Category: Partial Range Zone.

Age: Late Maastrichtian.

Occurrence: Chemchemal No. 2 (Tanjero Clastics Formation, 5410' - 5445'), Kirkuk No. 116 (Shiranish Formation, 4780' - 4785') and Pulkhana No. 5 (Shiranish Formation, 5415'- 5420').

Assemblage: *Arkhangelskiella cymbiformis, Chiastozygus amphipons, C. litterarius, Cribrosphaerella ehrenbergii, Eiffellithus gorkae, E. turriseiffelii, Gartnerago obliquum, Helicolithus trabeculatus, Lithraphidites* spp., *Microrhabdulus decoratus, M. undosus, Micula concava, M. murus, M. staurophora, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis, P. stoveri, Quadrum gothicum, Stradneria crenulata, Thoracosphaera operculata, Tranolithus minimus, Watznaueria barnesae* and *W. manivitae.*

Chronostratigraphic Significance: This zone is equivalent to the upper part of the *Tetralithus murus* Zone of Martini (1971) and the upper part of the *Micula mura* Zone of Okada and Bukry (1980).

6.3 Section Descriptions.

The 10 well sections studied to produce the calcareous nannofossil zonation scheme for this study are now discussed individually in detail below. The well logs, data sheets, distribution charts and abundance charts relating to each of the well sections can be viewed in Appendix A. In addition for each of the well sections studied the percentage individual species and groups of species have been averaged for each of the zones and subzones proposed in this study (see Tables 2a-q).

6.3.1 Atshan No. 1.

(See Atshan No. 1 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Atshan No. 1 well section was originally drilled on 25th. of March 1954, and occurs to the west of Mosul (E. 19 68.5, N. 32 71 64). In all 19 samples, 14 of which were drill cuttings and 5 of which were bit samples were taken from the Euphrates Limestone, Avanah Limestone/ Jaddala and the Khurmala Limestone/ Aaliji Formations.

The nannofossil assemblages in the samples from this well section are poorly preserved, with only Sample Nos. At-1/ 13 to At-1/ 17 yielding calcareous nannofossils. The nannofossil assemblages recorded in these samples are moderately overgrown with secondary calcite (O-2) and have a very low abundance rating (maximum number of nannofossils per fields of view 0.047).

The interval devoid of calcareous nannofossils between Sample Nos. At-1/ 1 and At-1/ 13, is taken from the Euphrates Limestone Formation and the upper part of the Avanah/ Jaddala Limestone Formations. This interval probably contains no calcareous nannofossils due to the sediments being hard, recrystallised limestones and marls, indicating that the sediments have undergone diagenetic alteration. These sediments are not generally suited to the preservation of calcareous nannofossil assemblages. In addition, this part of the sampled section contains nummulitic faunas which exploited shallower, platform margin areas not generally suited to the development and preservation of calcareous nannofossil assemblages.

The interval that yielded nannofossil assemblages between Sample Nos. At-1/ 13 and At-1/ 17 is taken from the lower part of the Avanah Limestone/ Jaddala Formations. In this part of the well section the sediments are soft and marly and contain an abundant microflora. This interval was tentatively assigned to the *Reticulofenestra dictyoda* Zone (IT6) based upon the range of *Reticulofenestra dictyoda* and the characteristic taxa contained within this zone. The *Reticulofenestra dictyoda* Zone (IT6) is at least 57 metres (191 feet) thick, however the top and base of the zone could not be accurately defined in this well section, as it becomes devoid of nannofossils before passing into another zone.

The nannofossil assemblages within the *Reticulofenestra dictyoda* Zone (IT6) are dominated by *Reticulofenestra scrippsae, R. bisecta, R. umbilica, Coccolithus pelagicus* and *Sphenolithus moriformis Group*, accounting for approximately 80 % of the total assemblage. These species are robust and solution resistent forms indicating that the sediments have been reworked and/ or suffered dissolution during their depositional history. Further evidence that reworking has occurred within the

Reticulofenestra dictyoda Zone (IT6), is illustrated by the fact that Cretaceous taxa including *Micula staurophora, Watznaueria barnesae, W. manivitae* and *Microrhabdulus undosus* consistently appear within this zone.

Finally, a single specimen of *Discoaster variabilis* an Early Miocene to Late Pliocene discoaster has caved from higher in the section possibly from the Euphrates Limestone Formation, as similar aged taxa have been retrieved from this formation in the I.P.C. Wells Bai Hassan No. 8 and Bai Hassan No. 10.

Summary:

A summary diagram showing the location and the main points of information gathered from Atshan No. 1 during this study can be seen Figure 6.2.

- 19 samples comprising 14 drill cutting and 5 bit samples were taken from the Euphrates Limestone, Avanah Limestone and the Khurmala Limestone/ Aaliji Formations.
- Only one poorly defined zone, the *Reticulofenestra dictyoda* Zone (IT6) which occurs between Sample Nos. At-1/ 13 and At-1/ 17 is recognised. The top of the zone is marked by the FDO of *Reticulofenestra dictyoda* and the base of the zone was not seen in this well section.
- The intervals devoid of calcareous nannofossils are probably the result of the sediments being diagenetically altered and having been formed in environments not generally suited to the preservation and development of calcareous nannofossil assemblages.

6.3.2 Bai Hassan No. 8. (See Bai Hassan No. 8 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Bai Hassan No. 8 well section occurs in the Bai Hassan Oil Field to the west of Kirkuk (Lat 35° 35' 42".57, Long. 44° 04' 22".38). The drilling for this well section commenced on the 25th. of November 1955 and was completed by the 28th. of April 1956, reaching a total depth of 9019 feet (2749 metres). In all 56 samples were selected from this well section comprising 54 conventional core samples and 2 drill cuttings. The formations sampled from this well section include the Lower Fars (Transition Beds), Euphrates Limestone, Bajawan Limestone, Baba Limestone, Tarjil and Palani Formations.

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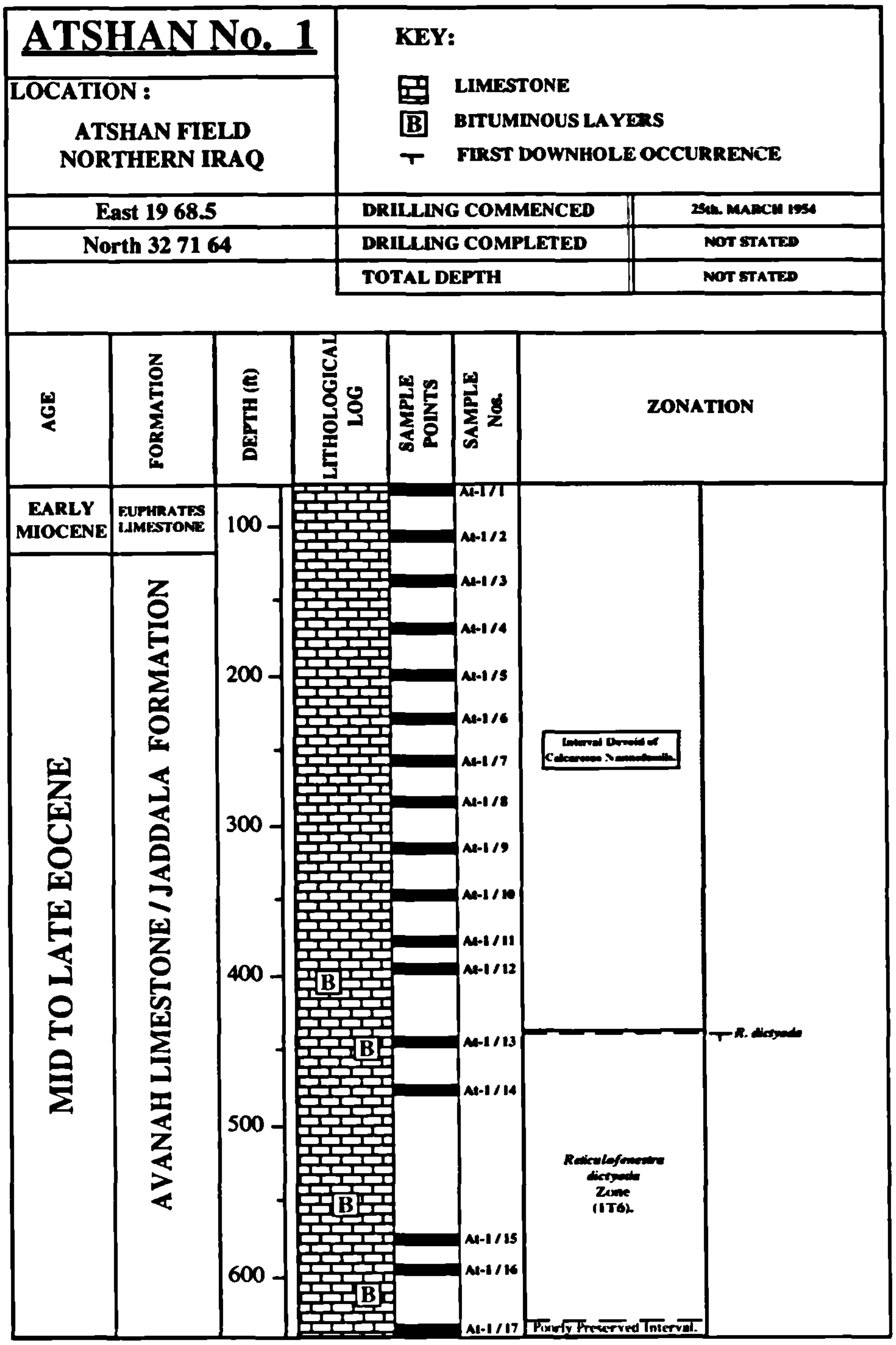

Figure 6. 2 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Atshan No. 1.

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Overall the Bai Hassan No. 8 well section is poorly preserved with 4 intervals that proved to be devoid of nannofossils:

1. Between Sample Nos. BH-8/ 2 and BH-8/ 4 (Lower Fars Formation, Transition Beds).
2. Between Sample Nos. BH-8/ 6 and BH-8/ 7 (Euphrates Limestone Formation).
3. Between Sample Nos. BH-8/ 9 and BH-8/ 10 (lowermost part of the Euphrates Limestone and uppermost part of the Bajawan Limestone Formations).
4. Between Sample Nos. BH-8/ 12 and BH-8/ 40 (lower part of the Bajawan Limestone and the uppermost part of the Baba Limestone).

These intervals comprise anhydritic, dolomitic and recrystallised sediments and therefore are not entirely suited to the preservation of calcareous nannofossils. The sediments also contain nummulitic, coral and molluscan faunas all of which inhabited shallow, platform margin conditions not generally suited to the preservation and developm ent of calcareous nannofossil assemblages.

The state of preservation of the calcareous nannofossil assemblages tend to be moderately to heavily overgrown with secondary calcite (O-2.5) and have a very low to low abundance ratings (number of nannofossils per field of view ranging from 0.003 to 2.857). Due to the general poor preservation state, it proved difficult to establish a zonation for this well section.

Towards the top of the Bai Hassan No. 8 well section 4 samples yielded nannofossil assemblages; BH-8/ 1, BH-8/ 5, BH-8/ 8 and BH-8/ 11. However, only sample BH-8/ 8 is thought to be of any consequence, and the other samples are believed to consist only of caved and reworked specimens. This judgement was based upon the low total numbers nannofossils counted (Sample No. BH-8/ 1 = 67, Sample No. BH-8/ 5 = 35 and Sample No. BH-8/ 11 = 8), the poor preservation state of the individual nannofossil specimens and the fact that the nannofossils are found in anhydritic, recrystallised, dolomitic limestones and marls which contain nummulites. These sediments are generally inappropriate for the preservation of calcareous nannofossils.

The sample BH-8/ 8 is poorly preserved and the nannofossil is moderately to heavily overgrown with secondary calcite (O-2.5), and has a very low abundance rating (maximum number of nannofossils per field of view 0.06). This sample has been taken from two marly intervals in the Euphrates Limestone Formation. The nannofossil assemblage for the sample BH-8/ 8 includes *Calcidiscus leptoporus, Coccolithus pelagicus, Cyclicargolithus abisectus, Discoaster deflandrei, Reticulofenestra haqii, R. productus,* and *Sphenolithus moriformis* Group. The sample is dominated by, *Coccolithus pelagicus, Reticulofenestra productus* and *Sphenolithus moriformis* Group, which constitutes 85.5% of the total nannofossil assemblage. These species are known to be fairly robust and solution resistent forms indicating that the sediments have undergone the effects of dissolution and/ or reworking during their depositional history. There is also some other evidence of reworking in the sample BH-8/ 8 noted by the presence of *Zygrhablithus bijugatus* within the sample, which must of been reworked from lower down in the well section. The sample BH-8/ 8 was not included in the zonation scheme as it is poor preservation and the nannofossil assemblage is only recognised in this one sample. However, the sample BH-8/ 8 was dated as Early to Mid Miocene (NN4 - NN5/ CN3 - CN4) based upon the nannofossil assemblage it contains. This interval was also suggested to occur in Atshan No. 1 well section based upon the caved appearance of *Discoaster variabilis* within the *Reticulofenestra dictyoda* Zone.

Though it has proved difficult to establish a zonation with the Bai Hassan No. 8 well section, the *Sphenolithus predistentus* Zone (IT4) has been tentatively assigned within the Tarjil Formation between sampled intervals BH-8/ 43 and BH-8/ 44. This zone was proposed, based upon the occurrence of *Sphenolithus predistentus* and the characteristic taxa contained within the zone. The *Sphenolithus predistentus* Zone (IT4) was also recognised based upon experience gained from the Tarjil Formation in the Kirkuk No. 85 well section. The *Sphenolithus predistentus* Zone (IT4) in this well section is at least 16.2 metres (54 feet) thick but, the top and bottom of the zone could not be accurately defined, as above and below this zone the sediments are poorly preserved and do not contain any recognisable marker species.

The Bai Hassan No. 8 well section, like Atshan No.1 well section is dominated by robust, solution resistent species. These include *Coccolithus pelagicus, Sphenolithus moriformis Group, Cyclicargolithus floridanus, Reticulofenestra bisecta* and *R. scrippsae*, and account for approximately 95% of total nannofossil assemblage within this well section.

Other taxa recognised from the *Sphenolithus predistentus* Zone (IT4) and the surrounding poorly preserved intervals include *Ericsonia obrupta, Helicosphaera euphratis* and *Zygrhablithus bijugatus*.

The base of the Bai Hassan No. 8 well section (sample BH-8/ 56) which samples the upper part of the Palani Formation is usually marked by the *Ericsonia subdisticha* Zone in other well sections for example Jambur No. 4, Kirkuk No. 85, Musaiyib No. 1 and Pulkhana No. 5. The *Ericsonia subdisticha* Zone (IT5) could not be recognised in the sample BH-8/ 56, but some of the characteristic taxa from this zone were recognised based upon the experience gained in the other well sections containing this zone. The characteristic taxa in the Bai Hassan No. 8 well section include *Braarudosphaera bigelowii, Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Zygrhablithus bijugatus*. The other characteristic taxa of the *Ericsonia subdisticha* Zone (IT5) recognised in the Bai Hassan No. 8 well section include the marker species *Ericsonia subdisticha* and *Discoaster barbadiensis*, which have been reworked along with *Thoracosphaera operculata* into the poorly preserved intervals and the *Sphenolithus predistentus* Zone (IT4) above.

Summary:

A summary diagram showing the location and the main points of information gathered from Bai Hassan No. 8 during this study can be seen in Figure 6.3. The main points of information gathered from this well section are:

- 56 samples comprising 54 conventional core and 2 drill cutting samples were taken from the Lower Fars (Transition Beds), Euphrates Limestone, Bajawan Limestone, Baba Limestone, Tarjil and Palani Formations.

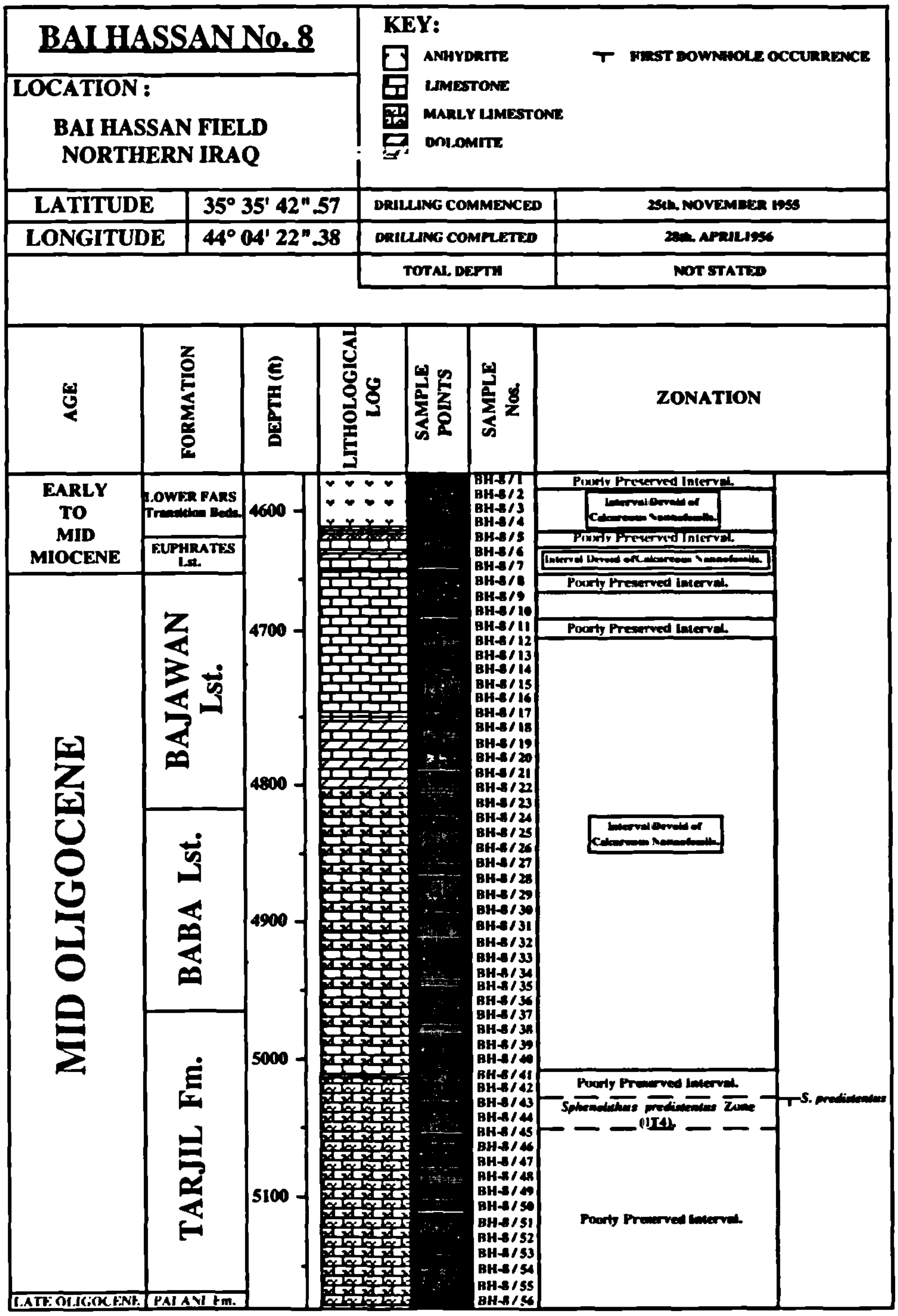

Figure 6. 3 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Bai Hassan No. 8.

- Sample No. BH-8/ 8 samples two marls in the Euphrates Limestone and contains a poorly preserved Mid Miocene (NN4 - NN5/ CN3 - CN4) calcareous nannofossil assemblage.
- Overall the well section is poorly preserved and only one poorly defined zone, the *Sphenolithus predistentus* Zone (IT4) which occurs between Sample Nos. BH-8/ 43 and BH-8/ 44 could be recognised. The zone is based upon the occurrence of *Sphenolithus predistentus* and the experience gained on the zone from the study of the Tarjil Formation in Kirkuk No. 85.
- The intervals devoid of calcareous nannofossils are the result of the sediments are not being suitable for the preservation of calcareous nannofossils. In addition the shallow, platform margin conditions in which the sediments were deposited are not generally suited to the preservation and development of calcareous nannofossil assemblages. These factors are indicated by the fact that the sediments are anhydritic, recrystallised and dolomitic and contain nummulitic, molluscan and coral faunas.

6.3.3 Bai Hassan No. 10. (See Bai Hassan No. 10 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Bai Hassan No. 10 well section is located in the Bai Hassan Oil Field to the west of Kirkuk (Long. 35° 35' 47".23, 44° 02' 24".43). The drilling of this well section commenced on the 3rd. of August 1956 and was completed by 5th. of October 1956 reaching a total depth of 4460 feet (1338 metres).

In all 40 samples were collected from the Lower Fars (Transition Beds), Euphartes Limestone, Anah Limestone, Azkand Limestone and Ibrahim Limestone Formations in this section. The samples from the Bai Hassan No. 10 well section comprises 33 conventional core and 7 drill cutting samples. In general the nannofossil assemblages within this well section are poorly preserved being moderately to heavily overgrown with secondary calcite (O-2.5) and have very low to low abundance ratings (number of nannofossils per field of view ranges from 0.018 to 2.675).

The Bai Hassan No. 10 well section contains two intervals that proved to be devoid of nannofossils. These intervals are from:

1. Between Sample Nos. BH-10/ 1 and BH-10/ 4 which samples the lowermost part of the Lower Fars (Transition Beds) to the uppermost part of the Euphrates Limestone Formations.
2. Between Sample Nos. BH-10/ 6 and BH-10/ 35 which samples the Anah Limestone and the Azkand

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Limestone Formations.

The sediments sampled within these intervals are dolomitic, anhydritic and recrystallised and are therefore not generally suited to the preservation of nannofossil assemblages. In addition these sediments contain corals, nummulites, lagoonal molluscans and ostracods, which accumulated in marginal marine environments not generally exploited by calcareous nannofossils.

In all only two intervals yielded nannofossil assemblages:

1. Between Sample Nos. BH-10/ 4 and BH-10/ 5, which samples the lowermost part of the Euphrates Limestone Formation.
2. Between Sample Nos. BH-10/ 35 and BH-10/ 40, which samples the base of the Azkand Limestone and the upper part of the Ibrahim Formation.

The first interval contains *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra productus, R. haqii, R. minuta* and *Sphenolithus moriformis* Group. The sample BH-10/ 4 is believed to be made up of reworked material from the sample BH-10/ 5. This based on the fact that the sample BH-10/ 4 has a particularly low number of nannofossils per field of view count, compared to the sample BH-10/ 5 (0.018 as apposed to 0.635 in sample BH-10/ 5). In addition, this relatively rich nannofossil assemblage in Sample No. BH-10/ 5 is also restricted to one sample in the near by Bai Hassan No. 8 well section.

The Sample No. BH-10/ 5 is poorly preserved, the nannofossil assemblage being moderately overgrown with secondary calcite (O-2). The nannofossil assemblage also has a very low abundance rating (number of nannofossils per field of view 0.635) and is dominated by *Coccolithus pelagicus, Cyclicargolithus floridanus* and *Reticulofenestra productus*, attaining a maximum of 90.2% of the total nannofossil assemblage. These species are known to be robust, solution resistent forms indicating that the sediments within this interval have undergone the effects of dissolution and/or reworking during their depositional history. There is good evidence that reworking has occurred as *Cyclicargolithus abisectus, Reticulofenestra bisecta, Ericsonia formosa, Quadrum gartneri, Micula murus, Toweius eminens, Watznaueria manivitae* and *Zygrhablithus bijugatus* all occur in this interval. This nannofossil-bearing interval was not included within the zonation scheme as it is poorly preserved and the nannofossil assemblage only occurs in one or possibly two samples in this well section. However this interval has been recognised in the Atshan No. 1 and Bai Hassan No. 8 well sections, and like these well sections Bai Hassan No. 10 has been dated as Early to Mid Miocene (NN4 - NN5/ CN3 - CN4) based upon the characteristic taxa it contains.

The other interval that yielded nannofossils (BH-10/ 35 to BH-10/ 40) samples soft and marly limestones which contain planktonic microfauna. This indicates the sediments accumulated a open marine environment, and these sediments are generally ideal for the preservation of calcareous nannofossils. However, the preservation state of the nannofossil assemblages within these sediments in this well section, is not as good as one would of expected. This is probably due to the effects of dolomitization on the sediments, and due to the fact that the sediments may not accumulated in a fully marine setting. The evidence for this latter point is based on the fact that the sediments contain ostracods, buliminids, shell debris and nummulites. These faunas indicate the sediments were laid down in slightly nearer shore brackish water conditions.

The interval between Sample Nos. BH-10/ 35 and BH-10/ 40 was assigned to the *Sphenolithus distentus* Zone (IT3) and is at least 43.5 metres (145 feet) thick in this well section. The top and bottom of the *Sphenolithus distentus* Zone (IT3) could not be accurately defined as the well section becomes devoid of nannofossils above sample BH-10/ 35, and there are no more samples available for collection below 4425 feet.

The nannofossil assemblages within the *Sphenolithus distentus* Zone (IT3) includes *Coccolithus pelagicus, Cyclicargolithus abisectus, C. floridanus, Reticulofenestra bisecta, R. scrippsae, Sphenolithus distentus, S. moriformis* Group and *Zygrhablithus bijugatus*. The zone also contains *Calcidiscus macintyrei, Reticulofenestra productus,* *R. haqii* and *Sphenolithus heteromorphosus* which have probably caved.

The *Sphenolithus distentus* Zone (IT3) is also dominated by *Coccolithus pelagicus, Cyclicargolithus abisectus, C. floridanus, Reticulofenestra bisectus* and *Sphenolithus moriformis* Group, accounting for approximately 94% of the total nannofossil assemblage. These species are robust and solution resistant forms indicating that dissolution and/ or reworking has effected the sediment during their depositional history. Further evidence that reworking has occurred in this zone is noted by the occurrence of *Discoaster tanii nodifer, Ericsonia formosa, E. robusta, E. subdisticha, Fasciculithus tympaniformis, Markalius inversus, Prediscosphaera grandis, Sphenolithus radians* and *Watznaueria barnesae* within the zone.

Summary:

A summary diagram showing the location and the main points of information gathered from Bai Hassan No. 10 during this study can be seen Figure 6.4. The main points of information gathered from this well section are:

- 40 samples comprising 33 conventional core and 7 drill cutting samples were taken from the Lower Fars (Transition Beds), Euphrates Limestone, Anah Limestone, Azkand Limestone and the Ibrahim Formations.
- Sample No. BH-10/ 5 samples the Euphrates Limestone and contains a poorly preserved Mid Miocene (NN4 - NN5/ CN3 - CN4) calcareous nannofossil assemblage.
- Overall the well section is poorly preserved and only one poorly defined zone, the *Sphenolithus distentus* Zone (IT3) which occurs between Sample Nos. BH-10 / 35 and BH-10 / 40 could be recognised. The top of the zone was defined by the FDO of Sphenolithus distentus but the base of the zone was not reached before the total depth of the well section was reached.
- The intervals devoid of calcareous nannofossils contain no nannofossils as the sediments are anhydritic, recrystallised and dolomitic in nature and are not suited to the preservation of calcareous nannofossils. The sediments also formed in marginal marine environments not generally exploited by calcareous nannofossils, as indicated by the by presence of nummulitic, lagoonal molluscan, coral and ostracod faunas within the sediments.

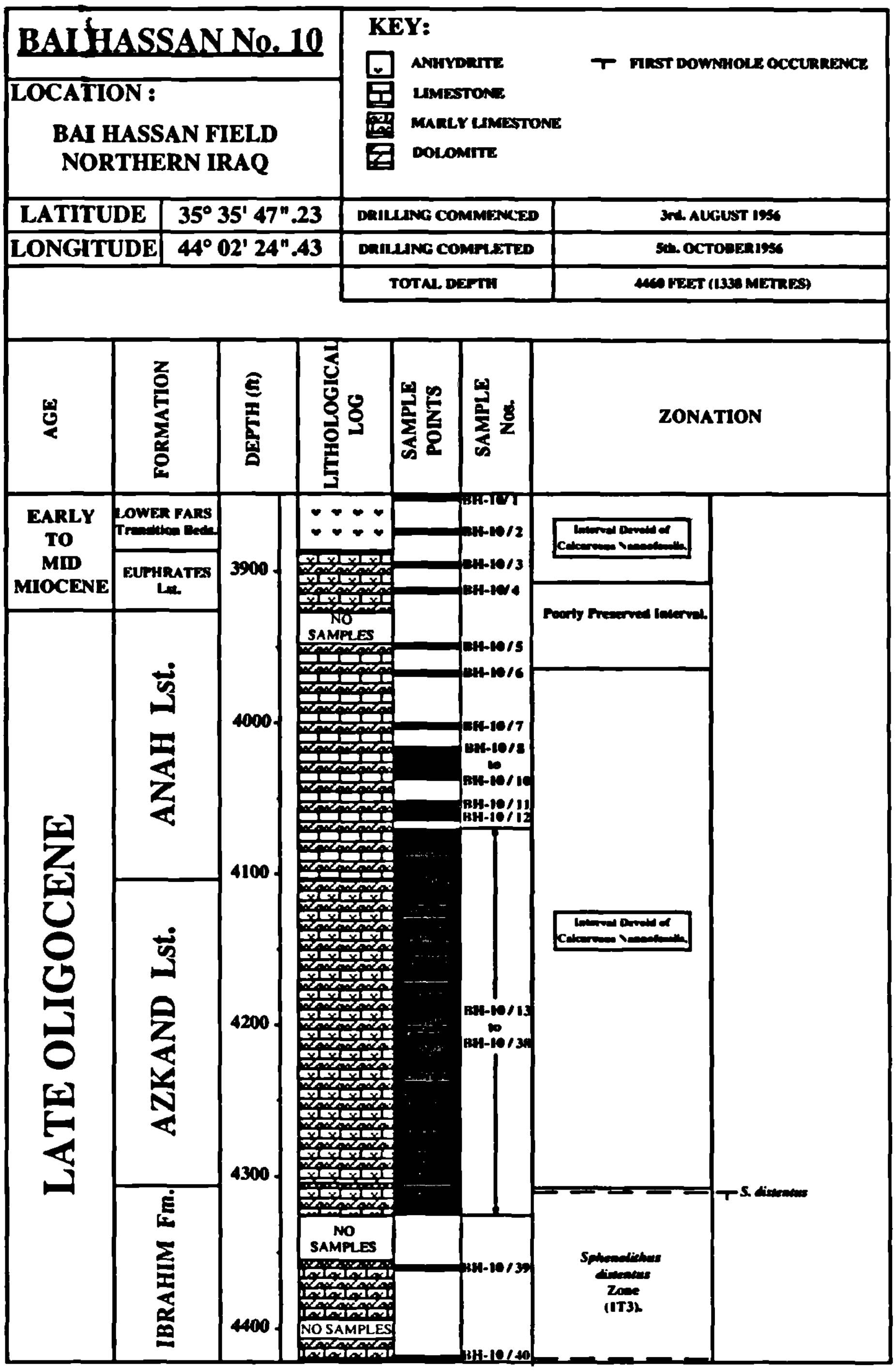


Figure 6.4 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Bai Hassan No. 10.

6.3.4 Jambur No. 4. (See Jambur No. 4 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Jambur No. 4 well section occurs to the south of Kirkuk in the Jambur Oil Field (Lat. 35° 07' 35".63, Long. 44° 35' 17".03). The drilling commenced on the 1st of November 1954 and was completed on the 11th. of September 1955 and reached a total depth of 7739 feet (2322 metres). In all 36 drill cutting samples were taken from the Lower Fars (Transition Beds), Jeribe Limestone, Dhiban Anhydrite, Serikagni and the Jaddala Formations.

The well section contains 4 intervals that are devoid of calcareous nannofossils:

1. Between Sample Nos. Ja-4/ 2 and Ja-4/ 8 which samples the lower par of the Lower Fars Formation (Transition Beds), Jeribe Limestone Formation and the upper part of the Dhiban Anhydrite.
2. Between Sample Nos. Ja-4/ 11 and Ja-4/ 12 which samples the Dhiban Anhydrite Formation.
3. Between Sample Nos. Ja-4/ 16 and Ja-4/ 22 which also samples the Dhiban Anhydrite Formation.
4. Sample No. Ja-4/ 24 which samples the lower part of the Dhiban Anhydrite Formation.

These intervals are probably devoid of nannofossils as they sample anhydritic and dolomitic limestones and marly limestones and bedded massive anhydrites, which are sediments not generally suited to the preservation of calcareous nannofossil assemblages. The limestones and marls also contain nummulite and molluscan faunas which inhabited shallow, more mariginal marine environments not generally suited to the preservation and development of calcareous nannofossil assemblages.

In all five intervals yielded calcareous nannofossil assemblages:

1. Sample No. Ja-4/ 1 samples the lower part of the Lower Fars Formation (Transition Beds).
2. Between Sample Nos. Ja-4/ 9 and Ja-4/ 10 samples the upper part of the Dhiban Anhydite Formation.
3. Between Sample Nos. Ja-4/ 13 and Ja-4/ 14 samples the middle part of the Dhiban Anhydrite Formation.
4. Sample No. Ja-4/ 23 samples the lower part of the Dhiban Anhydrite Formation.
5. Between Sample Nos. Ja-4/ 25 and Ja-4/ 36 samples the Serikagni Formation and the upper part of the Jaddala Formation.

The state of preservation within these intervals is somewhat patchy. The nannofossil assemblages range from being slightly overgrown (O-1) to being moderately to heavily overgrown (O-2.5) with secondary calcite. These nannofossil assemblages also have very low to low abundance ratings (number of nannofossils per field of view ranges from O.003 to 7.342).

The first interval (Sample No. Ja-1/ 1) samples the lowermost part of the Lower Fars Formation (Transition Beds). The nannofossil assemblage is relatively well preserved, being only slightly overgrown (O-1) with secondary calcite. Despite this generally good state of preservation the nannofossil assemblage still has a low abundance rating (number of nannofossils per field of view 7.342). The nannofossil assemblage in this interval includes *Calcidiscus leptoporus, Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra productus, Discoaster druggii, Helicosphaera euphratis, Reticulofenestra haqii, Rhabdolithus spp., Sphenolithus conicus, S. heteromorphus, S. moriformis* and *S. moriformis* Group. The Sample No. Ja-4/ 1 is supposedly taken from an anhydrite bed but, it is actually made up of a red brown marl which has caved. This interval also contains nannofossils from the Late Miocene/ Pliocene, these include *Helicosphaera sellii, Reticulofenestra pseudoumbilica* and *Sphenolithus neoabies.*

The Sample No. Ja-4/ 1 also shows strong evidence for reworking as it also contains *Campylosphaera eodela, Chiasmolithus grandis, Cribrosphaerella ehrenbergii, Cyclicargolithus abisectus, Discoaster bardadiensis, D. tanii nodifer, Ericsonia formosa, E. obrupta, E. subdisticha, Fasciculithus tympaniformis, Helicosphaera compacta, Ismolithus recurvus, Microrhabdulus undosus, Micula murus, M. staurophora, Nannotetrina fulgens, Neochiastozygus distentus, Prediscosphaera grandis, Quadrum gartneri, Reticulofenestra bisecta, R. callida, R. minuta, R. scrippsae, R. umbilica, Sphenolithus ciperoensis, S. predistentus, S. radians, Thoracosphaera operculata, Tranversopontis rectipons, Tribrachiatus orthostylus* B, *Watznaueria manivitae, Zygodiscus bramlettei* and *Zygrhablithus bijugatus*, from the Late Cretaceous, Palaeocene, Early Eocene, Mid Eocene, Late Oligocene and Early Miocene. Additional evidence that reworking has occurred within sample no. Ja-4 / 1 is based upon the fact the sample is dominated by *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra productus* and *Sphenolithus moriformis* Group, which accounts for 71.5% of the total nannofossil assemblage.

The next 3 intervals that yielded nannofossil assemblages below Sample No. Ja-4/ 1:

1. Between Sample Nos. Ja-4/ 9 and Ja-4/ 10 from the Dhiban Anhydrite Formation.
2. Between Sample Nos. Ja-4/ 13 and Ja-4/ 14 from the Dhiban Anhydrite Formation.
3. Sample No. Ja-4/ 23 from the Dhiban Anhydrite Formation.

These three intervals are believed to contain caved nannofossils which include *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra productus* and *Sphenolithus moriformis* Group from the relatively rich nannofossil assemblage in the sample Ja-4/ 1. This interpretation was based upon the low total numbers nannofossils counted and the general inappropriate nature of the lithologies for the preservation of calcareous nannofossils.

The final interval that yielded calcareous nannofossils (from Sample No. Ja-4/ 25 to Sample No. Ja-4/ 36) samples the Serikagni and Jaddala Formations. Altogether, three zones were assigned to this interval: *Cylicargolithus abisectus* Zone (IT1), *Reticulofenestra bisecta* Zone (IT2) and Ericsonia subdisticha Zone (IT5).

1. *Cyclicargolithus abisectus* Zone (IT1).

This zone occurs at the top of the Serikagni Formation between Sample Nos. Ja-4/ 25 and Ja-4/ 26, and is 18 metres (60 feet) thick in the Jambur No. 4 well section. The upper limit of the *Cyclicargolithus abisectus* Zone (IT1) has not been accurately defined as the well section becomes devoid of calcareous nannofossils before passing into another zone. The point at which the section becomes devoid of nannofossils is marked by a change in lithologies and formations from the marly globigerinid limestones of the Serikagni Formation to a sequence of anhydrites and dolomitic, anhydritic and recrystallised marls and limestones of the Dhiban Anhydrite Formation. The base of the *Cyclicargolithus abisectus* Zone (IT1) is defined by the top of the underlying zone, which is marked by the FDO of *Reticulofenestra bisecta*. The nannofossil assemblage in the *Cyclicargolithus abisectus* Zone (IT1) is moderately to heavily overgrown (O-2 to O-2.5) with secondary calcite. The nannofossil assemblage also has very low to low abundance ratings (number of nannofossils per field of view 0.01 and 1.659), and assemblage includes *Coccolithus pelagicus, Cyclicargolithus* *abisectus, C. floridanus, Helicosphaera scissura* and *Sphenolithus moriformis* Group. The *Cyclicargolithus abisectus* Zone (IT1) is dominated by *Coccolithus pelagicus, Cyclicargolithus abisectus, C. floridanus* and *Sphenolithus moriformis* Group, which account for approximately 90% of the total nannofossil assemblage. These species are generally robust and solution resistant forms and indicating that the sediments in this zone may have suffered from the effects of dissolution and/ or reworking during their depositional history.

2. *Reticulofenestra bisecta* Zone (IT2).

This zone occurs in the lower part of the Serikagni Formation between Sample Nos. Ja-4/ 27 and Ja-4/ 33, and is 54 metres (180 feet) thick. The *Reticulofenestra bisecta* Zone (IT2) is defined from the FDO *Reticulofenestra bisecta* to the FDO *Ericsonia subdisticha*, in this well section. The nannofossil assemblage in this zone is moderately to heavily overgrown (O-2 to O-2.5) with secondary calcite and has very low to low abundance ratings (number of nannofossils per field of view ranges from 0.016 to 5.351). The *Reticulofenestra bisecta* Zone (IT2) contains the same taxa as the zone above with the addition of *Discoaster deflandrei, Helicosphaera euphratis, Pontosphaera spp., Sphenolithus dissimilis*, and the exclusion of *Helicosphaera scissura*. This zone is dominated by the occurrence of *Coccolithus pelagicus, Cyclicargolithus abisectus, C. floridanus, Reticulofenestra bisecta* and *Sphenolithus moriformis* Group making up to 99% of the total nannofossil assemblage. These species are robust and solution resistent forms which suggests that the sediments making up this zone underwent the effects of dissolution and/ or reworking during their depositional history. The number of nannofossils per field of view drops considerably in the last two samples (Sample Nos. Ja-4/ 29 and No. Ja-4/ 30) in the base of the *Reticulofenestra bisecta* Zone (IT2). These samples may be a reflecting of the hiatus between the *Reticulofenestra bisecta* Zone (IT2) above and the *Ericsonia subdisticha* Zone (IT5) below. The hiatus between the *Reticulofenestra bisecta* Zone (IT2) and the *Ericsonia subdisticha* Zone (IT5) spans the top of the Early Oligocene to the base of the Latest Oligocene (NP22 to NP24/ CP22c to CP19b).

3. *Ericsonia subdisticha* Zone (IT5).

This zone occurs at the upper part of the Jaddala Formation and is defined between Sample Nos. Ja-4/ 33 and Ja-4/ 36 and is 28.5 metres (95 feet) thick. The top of this zone is marked by the FDO *Ericsonia subdisticha* and the bottom of this zone is not reached before the end of the sampled section in Jambur No. 4 is reached. The *Ericsonia subdisticha* Zone (IT5) contains the same taxa as the zone above with the addition of *Ericsonia subdisticha, Helicosphaera compacta, Pyrocyclus hermosus, Reticulofenestra minuta, Zygrhablithus bijugatus,* and the exclusion of *Sphenolithus dissimilis.* The Jaddala Formation in other well sections during this study have been assigned to the *Reticulofenestra dictyoda* Zone (IT6) and *Reticulofenestra callida* Zone (IT7) which is Mid Eocene in age. However the formation in the Jambur No.4 well section has been assigned to the *Ericsonia subdisticha* Zone (IT5) which usually is represented by the Early Oligocene, Palani Formation. Therefore, it is suggested that the Jaddala Formation has been incorrectly assigned to this part of the Jambur No. 4 well section, and the formation sampled is the Palani Formation. This previous incorrect assignment of formations can be explained by the fact that the Palani and Jaddala Formations are very similar lithologically, both being typically soft, marly, globigerinid limestones. The *Ericsonia subdisticha* Zone (IT5) like the other two zones in this well section, is dominated by the robust, solution resistant forms which include *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Sphenolithus moriformis* Group, which make up to 95% of the total nannofossil assemblage. The dominance of robust and solution resistant forms suggests that the sediments have undergone dissolution and/ or reworking during their depositional history.

Summary:

A summary diagram showing the location and the main points of information gathered from Jambur No. 4 during this study can be seen Figure 6.5. The main points of information gathered from this well section are:

- 35 drill cutting samples taken from the Lower Fars (Transition Beds), Jeribe Limestone, Dhiban Anhydrite, Serikagni and Jaddala Formations.

6.0 Biostratigraphy

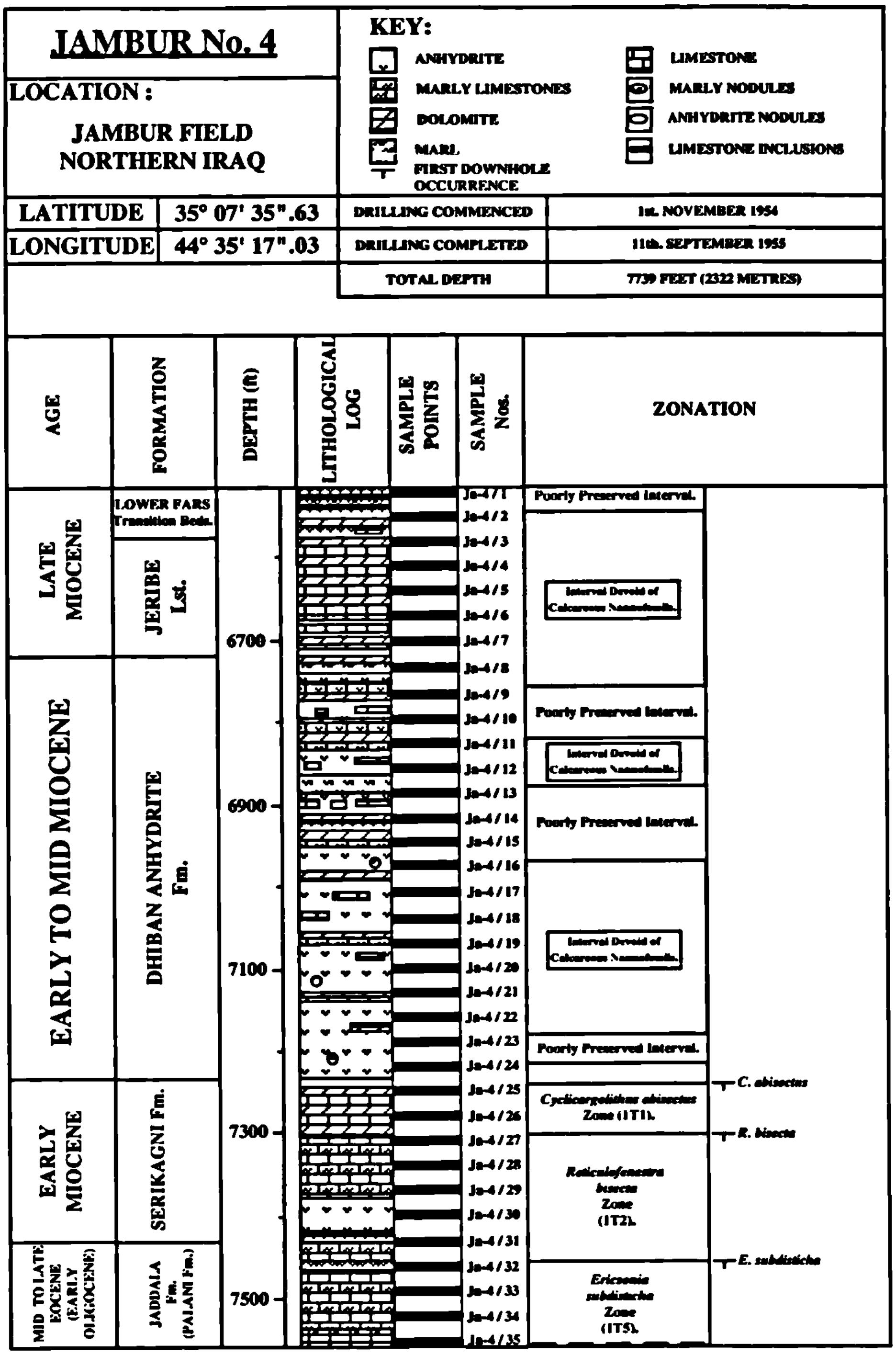


Figure 6. 5 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Jambur No. 4.

- Sample No. Ja-4/ 1 samples the Lower Fars (Transition Beds) and contains a poorly preserved Late Miocene/ Pliocene calcareous nannofossil assemblage but, the sample is mainly made up of reworked Late Cretaceous, Palaeocene, Early Eocene, Mid Eocene, Late Oligocene and Early Miocene taxa.
- Overall the Jambur No. 4 well section is poorly preserved but 3 zones recognised in this well section:

  1. *Cyclicargolthus abisectus* Zone (IT1). Between Sample Nos. Ja-4/ 25 and Ja-4/ 26 from the Serikagni Formation.

  2. *Reticulofenestra bisecta* Zone (IT2). Between Sample Nos. Ja-4/ 27 and Ja-4/ 32 also from the Serikagni Formation.

  3. *Ericsonia subdisticha* Zone (IT5). Between Sample Nos. Ja-4/ 33 and Ja-4/ 35 from the Palani Formation.
- The intervals devoid of calcareous nannofossils are the result of the sediments are not being suitable for the preservation of calcareous nannofossils. In addition the shallow, marginal marine conditions in which the sediments were deposited are not generally suited to the preservation and development of calcareous nannofossil assemblages. These factors are indicated by the fact that the sediments are anhydritic, recrystallised and dolomitic and contain nummulitic and molluscan faunas.

6.3.5 Rachi No. 1. (See Rachi No. 1 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Rachi No. 1 well section was originally drilled on June the 5th. 1956, and occurs in the extreme southeast of Iraq, close to the Kuwaiti border and southwest of Basrah, west of the Rumaila Oil Field (E.1,696,206,35, N.917,338,63). In all 102 drill cutting samples were taken from the Abu Ghar, Dammam Limestone, Rus Anhydrite, Umm Er Radhuma and Tayarat Limestone Formations.

The overall preservation state of the sampled section in the Rachi No. 1 well section is poor, the nannofossil assemblages being slightly to moderately overgrown (O-1 to O-2) with secondary calcite and has very low to low abundance ratings (number of nannofossils per field of view ranges from 0.001 to 6.522).

This well section contains 11 intervals that are devoid of calcareous nannofossils:

1. Between Sample Nos. Ra-1/ 5 and Ra-1/ 7 (basal part of the Abu Ghar Formation and the upper part of

the Dammam Limestone Formation).

2. Between Sample Nos. Ra-1/ 10 and Ra-1/ 18 (Dammam Limestone Formation).
3. Between Sample Nos. Ra-1/ 20 and Ra-1/ 23 (Dammam Limestone Formation).
4. Between Sample Nos. Ra-1/ 32 and Ra-1/ 34 (upper part of the Rus Anhydrite Formation).
5. Sample No. Ra-1/ 42 (Rus Anhydrite Formation).
6. Between Sample Nos. Ra-1/ 47 and Ra-1/ 49 (basal part of the Rus Anhydrite Formation).
7. Between Sample Nos. Ra-1/ 55 and Ra-1/ 56 (upper part of the Umm Er Radhuma Formation).
8. Between Sample Nos. Ra-1/ 59 and Ra-1/ 63 (Umm Er Radhuma Formation).
9. Between Sample Nos. Ra-1/ 66 and Ra-1/ 76 (Umm Er Radhuma Formation).
10. Between Sample Nos. Ra-1/ 78 and Ra-1/ 85 (Umm Er Radhuma Formation).
11. Between Sample Nos. Ra-1/ 90 and Ra-1/ 101 (basal part of the Umm Er Radhuma Formation).

These intervals sample dolomitized, recrystallised and anhydritic marls and limestones, and massive bedded anhydrites. These sediments are not generally suited to the preservation of calcareous nannofossil assemblages, and in addition they contain nummulite and molluscan faunas which inhabited shallow, marginal marine environments not generally suited to the preservation and development of calcareous nannofossil assemblages.

The 12 intervals that yielded calcareous nannofossils are:

1. Between Sample Nos. Ra-1/ 1 and Ra-1/ 4 (Abu Ghar Formation).
2. Between Sample Nos. Ra-1/ 8 and Ra-1/ 9 (upper part of the Dammam Limestone Formation).
3. Sample No. Ra-1/ 19 (Dammam Limestone Formation).
4. Between Sample Nos. Ra-1/ 24 and Ra-1/ 31 (basal part of the Dammam Limestone Formation).
5. Between Sample Nos. Ra-1/ 35 and Ra-1/ 41 (Rus Anhydrite Formation).
6. Between Sample Nos. Ra-1/ 43 and Ra-1/ 46 (Rus Anhydrite Formation).
7. Between Sample Nos. Ra-1/ 50 and Ra-1/ 54 (upper part of the Umm Er Radhuma Formation).
8. Between Sample Nos. Ra-1/ 57 and Ra-1/ 58 (Umm Er Radhuma Formation).
9. Between Sample Nos. Ra-1/ 64 and Ra-1/ 65 (Umm Er Radhuma Formation).
10. Sample No. Ra-1/ 77 (Umm Er Radhuma Formation).
11. Between Sample Nos. Ra-1/ 86 and Ra-1/ 89 (Umm Er Radhuma Formation).
12. Sample No. Ra-1/ 102 (upper part of the Tayarat Formation).

The majority of the intervals that yielded calcareous nannofossils, which are listed above, are believed to be made up of caved and reworked occurrences. This based upon the fact that these intervals are made up of nannofossil assemblages that have low diversities and low abundances, in addition the species making up these nannofossil assemblages are common above and/ or below these intervals. Only 3 intervals from the 12 intervals listed above are believed to show true occurrences of nannofossil assemblages these are: between Sample Nos. Ra-1/ 1 and Ra-1/ 4 (Abu Ghar Formation), Sample Nos. Ra-1/ 24 and Ra-1/ 31 (basal part of the Dammam Limestone Formation, Sample Nos. Ra-1/ 35 and Ra-1/ 41 (Rus Anhydrite Formation). These are now described in detail in descending stratigraphic order.

The interval between Sample Nos. Ra-1/ 1 and Ra-1/ 4 samples the Abu Ghar Formation, yielded calcareous nannofossil assemblages that are slightly to moderately overgrown (O-1.5 to O-2) with secondary calcite. These nannofossil assemblages also have very low abundance ratings (number of nannofossils per field of up to 0.035) but, are relatively diverse containing *Calcidiscus macintyrei, Coccolithus pelagicus, Cyclicargolithus floridans, Helicosphaera euphratis, H. scissura, Reticulofenestra minuta, R. productus* and *R. pseudoumbilica*. This interval is dominated by the robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra haqii, R. productus* and *R. pseudoumbilica*, making up to 95% of the total nannofossils assemblage. This evidence suggests that the sediments within this interval have undergone the effects of dissolution and/ or reworking during their deposition history. There is additional evidence that reworking has occurred as *Chiastozygus litterarius, Micula concava* and *Watznaueria manivitae* all from the Cretaceous occur within this interval. The nannofossil assemblage within this interval was not zoned due to its low abundance but, has been tentatively dated as Mid Miocene (NN5/ CN4). This date assigned to the Abu Ghar Formation is comparable in age to that assigned to the thin marly intervals within the Euphrates Limestone Formation in the Bai Hassan No. 8 and 10 well sections. This same interval was also suggested to occur in the Atshan No. 1 well section.

The intervals between Sample Nos. Ra-1/ 24 and Ra-1/ 31, and Sample Nos. Ra-1/ 35 and Ra-1/ 41 which sample the lower part of the Dammam Limestone Formation and the Rus Anhydrite Formation contains nannofossil assemblages that are moderately overgrown (O-2) with secondary calcite and have very low to low abundance ratings (number of nannofossils per field of view ranges from 0.006 to 6.522). Despite the poor preservation 2 zones have been assigned in these intervals; the *Reticulofenestra dictyoda* Zone (IT6) and the *Reticulofenestra callida* Zone (IT7).

1. *Reticulofenestra dictyoda* Zone (IT6).

The *Reticulofenestra dictyoda* Zone occurs between Sample Nos. Ra-1/ 24 and Ra-1/ 37, but is split in this well section by an interval devoid of calcareous nannofossils. The top of the zone cannot be accurately defined as the well section becomes devoid of calcareous nannofossils before entering another zone and the base of the zone is marked by the FDO of *Reticulofenestra callida*. The *Reticulofenestra dictyoda* Zone (IT6) overall is 135 metres (450 feet) thick (including the interval devoid of calcareous nannofossils), and contains *Braarudosphaera bigelowii, Chiasmolithus consuetus, C. grandis, C. solitus, Coccolithus pelagicus, Cyclicargolithus floridanus, Discoaster barbadiensis, D. gemmeus, D. wemmelensis, Ericsonia obrupta, E. formosa, Helicosphaera euphratis, H. seminulum, Markalius inversus, Pontosphaera spp., P. multipora, Rhabdolithus spp., Reticulofenestra bisecta, R. scrippsae, R. dictyoda, R. umbilica, Sphenolithus moriformis* Group, *S. radians, Transversopontis obliquipons, T. rectipons* and *Zygrhablithus bijugatus*.

2. *Reticulofenestra callida* Zone (IT7).

The *Reticulofenestra callida* Zone only occurs in one sample Ra-1/ 38 and is 9 metres (30 feet) thick in this well section. The top of the zone is defined by the FDO *Reticulofenestra callida* but, the base of the zone is not seen as the well section becomes devoid of calcareous nannofossils before entering another zone. The *Reticulofenestra callida* Zone (IT7) contains *Birkelundia staurion, Coccolithus pelagicus, Cyclicargolithus floridanus, Ericsonia formosa, E. obrupta, Reticulofenestra bisecta, R. callida, R. dictyoda, R. scrippsae, R. umbilica, Sphenolithus moriformis* Group and *Zygrhablithus bijugatus*.

The poorly preserved interval below the *Reticulofenestra callida* Zone (IT7) contains *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra scrippsae, R.*

dictyoda, R. umbilica and *Sphenolithus moriformis* Group.

Summary:

A summary diagram showing the location and the main points of information gathered from Rachi No. 1 during this study can be seen Figure 6.6. The main points of information gathered from this well section are:

- 102 drill cutting samples taken from the Abu Ghar, Dammam Limestone, Rus Anhydrite, Umm Er Radhuma and Tayarat Formations.
- The interval between Sample Nos. Ra-1/ 1 and Ra-1/ 4 is taken from the Abu Ghar Formation and contains poorly preserved Mid Miocene (NN5/ CN4) nannofossil assemblages, comparable in age to the nannofosssil assemblages within the thin marly intervals within Euphrates Limestone Formation in Bai Hassan Nos. 8 and 10 well sections. In addition the calcareous nannofossil assemblages in the Rachi No. 1 well section contain reworked Cretaceous taxa like the Bai Hassan Nos. 8 and 10 well sections.
- Overall the Rachi No. 1 well section is poorly preserved but 2 zones can be defined in this well section:

  1. *Reticulofenestra dictyoda* Zone (IT6). Between Sample Nos. Ra-1/ 24 and Ra-1/ 37 from the lower part of the Dammam Limestone Formation and the Rus Anhydrite Formation.
  2. *Reticulofenestra callida* Zone (IT7). Sample No. Ra-1/ 38 also from the Rus Anhydrite Formation.
- The intervals devoid of calcareous nannofossils are the result of the sediments are not being suitable for the preservation of calcareous nannofossils. In addition the shallow, marginal marine conditions in which the sediments were deposited are not generally suited to the preservation and development of calcareous nannofossil assemblages. These factors are indicated by the fact that the sediments are anhydritic, recrystallised and dolomitic and contain nummulitic and molluscan faunas.

6.3.6 Musaiyib No.1. (See Musaiyib No. 1 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Musaiyib No. 1 well section was originally drilled on the 3rd of December 1957, and occurs the south of Baghdad close to the Euphrates River (E.1,445,000, N.1,201,000). In all 24 drill cutting samples were collected from the Bajawan Limestone, Baba Limestone, Shurau Limestone, Sheik Alas Limestone, Palani and the Jaddala Formations.

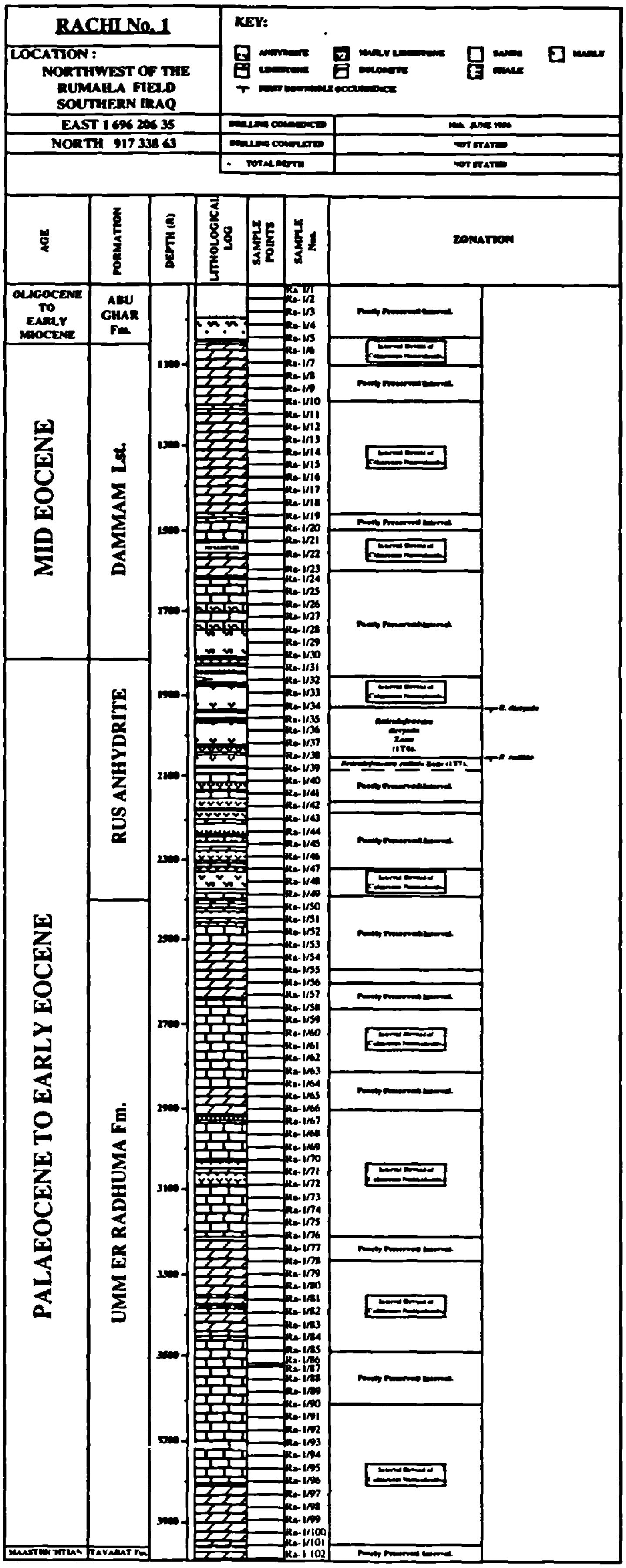


Figure 6.6 Summary Diagram of the Main Biostratigraphic Information from M.P.C. Well Rachi No. 1.

6.0 Biostratigraphy

The top of the sampled section between Sample Nos. Mu-1/ 1 and Mu-1/ 5 is taken from the Bajawan Limestone, Baba Limestone, Shurau Limestone and the upper part of the Sheik Alas Limestone Formations and proved to be devoid of calcareous nannofossils. This interval contains no calcareous nannofossil assemblages as the sediments sampled are recrystallised and dolomitic in nature. In addition the limestones contain nummulites which developed in shallow, platform margin conditions not generally suited to the preservation and development of calcareous nannofossil assemblages.

The interval between Sample Nos. Mu-1/ 6 and Mu-1/ 9 is poorly preserved, and samples the lower part of the Sheik Alas Limestone. The nannofossil assemblage in this poorly preserved interval is moderately to heavily overgrown (O-2.5) with secondary calcite, and has very low abundance ratings (number of nannofossils per field of view ranging from 0.013 to 0.108). The poor preservation is probably due to the fact that recrystallised and dolomitic limestones are sampled which are generally not suited to good nannofossil preservation. The poorly preserved interval contains *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, Helicosphaera euphratis, Pontosphaera multipora, Sphenolithus moriformis* Group and *Zygrhablithus bijugatus* but, is dominated by robust solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Sphenolithus moriformis* Group which make up to 100% of the total nannofossil assemblage.

The interval between Sample Nos. Mu-1/ 10 and Mu-1/ 24 below the poorly preserved interval has been assigned to the *Ericsonia subdisticha* Zone (IT5) and the *Reticulofenestra dictyoda* Zone (IT6). This interval is generally better preserved, the nannofossil assemblages being slightly to moderately overgrown (O-1.5) with secondary calcite, and have low to moderate abundance ratings (number of nannofossils per field of view ranging from 5 to 18.412).

6.0 Biostratigraphy

1. *Ericsonia subdisticha* Zone (IT5).

This zone samples the globigerinid marly limestone of the Palani Formation and occurs between Sample Nos. Mu-1/ 10 and Mu-1/ 23 and is 126 metres (420 feet) thick in this well section. The *Ericsonia subdisticha* Zone (IT5) is defined from the FDO *Ericsonia subdisticha* to the FDO *Reticulofenestra dictyoda* and contains *Braarudosphaera bigelowii, Coccolithus pelagicus, Chiasmolithus titus, Cyclicargolithus floridanus, Discoaster tanii, Ericsonia formosa, E. obrupta, E. subdisticha, Helicosphaera bramlettei, H. compacta, H. euphratis, H. minima, Pontosphaera spp., P. multipora, Pyrocyclus hermosus, Reticulofenestra bisecta, R. scrippsae, R. hillae, R. minuta, R. umbilica, Rhabdolithus spp., R. tenuis, Sphenolithus moriformis, S. moriformis* Group, *S. predistentus, Traversopontis obliquipons* and *Zygrhablithus bijugatus*. Despite the diversity of the *Ericsonia subdisticha* Zone (IT5) it is dominated by robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. hillae, R. minuta, R. scrippsae,* R. umbilica and *Sphenolithus moriformis* Group making up to 90% of the total nannofossil assemblage. The dominance of these robust, solution resistant forms suggests that the sediments within this zone have undergone the effects of dissolution and/ or reworking during their depositional history. Further evidence that reworking has taken place within the *Ericsonia subdisticha* Zone (IT5), is noted by the occurrence of *Reticulofenestra callida* and *Thoracosphaera operculata* within the zone reworked from intervals below.

2. *Reticulofenestra dictyoda* Zone (IT6).

This zone occurs at the base of the sampled section in Musaiyib No. 1 in Sample No. Mu-1/ 24 and is 1.5 metres (5 feet) thick. The top of this zone is marked by the FDO of *Reticulofenestra dictyoda* but, the base of the zone is not seen as no more samples were collected below Sample No. Mu-1/ 24. The *Reticulofenestra dictyoda* Zone (IT6) contains *Coccolithus pelagicus, Cyclicargolithus floridanus, Ericsonia formosa, Helicosphaera compacta, H. euphratis, Pontosphaera spp., Pyrocyclus hermosus, Reticulofenestra bisecta, R. minuta, R. scrippsae, R. umbilica, Rhabdolithus* spp., *Sphenolithus moriformis* Group, *S. predistentus* and *Zygrhablithus bijugatus*. The

Reticulofenestra dictyoda Zone (IT6) like the *Ericsonia subdisticha* Zone is dominated by robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. minuta, R. scrippsae, R. umbilica* and *Sphenolithus moriformis* Group, which makes up 76% of the total nannofossil assemblage. This fact suggests that the interval has undergone the effects of dissolution and/ or reworking during its depositional history. Further evidence for reworking in the *Reticulofenestra dictyoda* Zone (IT6) is noted by the occurrence of *Thoracosphaera operculata*. The *Reticulofenestra dictyoda* Zone (IT6) also contains caved examples of *Ericsonia subdisticha* and *Discoaster tanii*.

Summary:

A summary diagram showing the location and the main points of information gathered from Musaiyib No. 1 during this study can be seen figure 6.7. The main points of information gathered from this well section are:

- 24 drill cutting samples taken from the basal part of the Bajawan Limestone, Baba Limestone, Shurau Limestone, Shiek Alas Limestone, Palani and Jaddala Formations.
- Overall the Rachi No. 1 well section is fairly well preserved and 2 zones can be defined in this well section:

  1. *Ericsonia subdisticha* Zone (IT5). Sample No. Mu-1/ 10 to Sample No. Mu-1/ 23 from the Palani Formation.

  2. *Reticulofenestra dictyoda* Zone (IT6). Sample No. Mu-1/ 24 from the upper part of the Jaddala Formation.
- The intervals devoid of calcareous nannofossils are the result of the sediments are not being suitable for the preservation of calcareous nannofossils. In addition the shallow, platform margin conditions in which the sediments were deposited are not generally suited to the preservation and development of calcareous nannofossil assemblages. These factors are indicated by the fact that the sediments are anhydritic, recrystallised and dolomitic and contain nummulitic faunas.

6.3.7 Kirkuk No. 85. (See Kirkuk No. 85 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Kirkuk No. 85 well section is located in northern Iraq, within the Kirkuk Oil Field, slightly to the east of Kirkuk (Lat. 35° 26' 42" N, Long. 44° 25' 28" E). In all 37 drill cuttings samples were collected from the Tarjil, Palani, and Jaddala

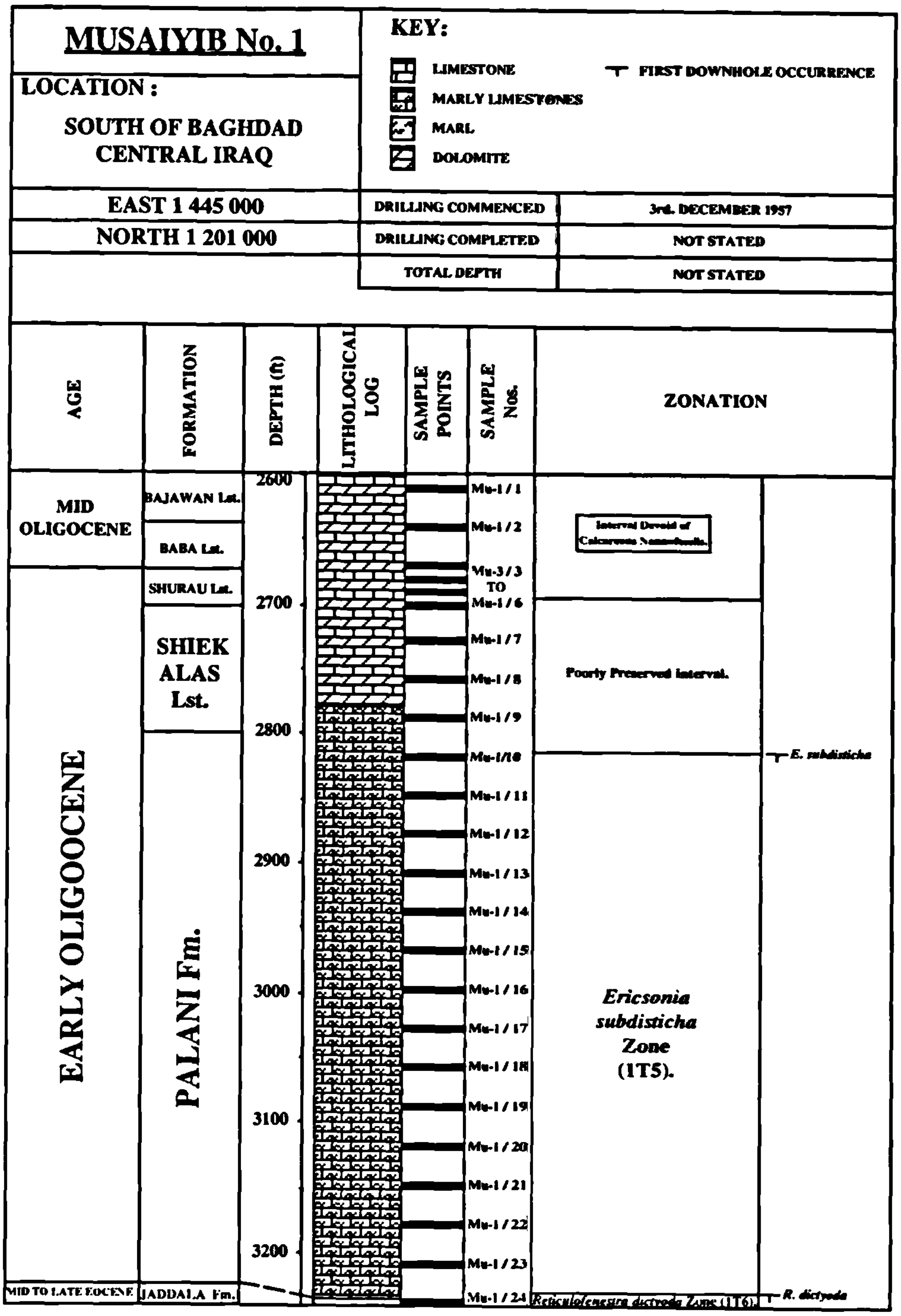


Figure 6. 7 Summary Diagram of the Main Biostratigraphic Information from M.P.C. Well Musaiyib No. 1.

Formations. Overall the nannofossil assemblages in the samples from this well section are poorly preserved, being moderately to heavily overgrown (O-2.5) with secondary calcite and have very low to low abundances (number of nannofossils per field of view ranges from 0.038 to 7.537).

In all 4 zones were defined in this well section:

1. ***Sphenolithus predistentus*** **Zone (IT4).**
2. ***Ericsonia subdisticha*** **Zone (IT5).**
3. ***Reticulofenestra dictyoda*** **Zone (IT6).**
4. ***Reticulofenestra callida*** **Zone (IT7).**

However, above these zones a 10.5 metre (35 feet) thick poorly preserved interval within the upper part of Tarjil Formation occurs from Sample No. K-85/ 1 to Sample No. K-85/ 2. The nannofossil assemblage within this poorly preserved interval is moderately to heavily overgrown (O-2.5) with secondary calcite and has very low abundance ratings (number of nannofossils per field of view 0.038 and 0.839). The interval was not zoned as it is to poorly preserved and contains none of the recognised marker species. The nannofossil assemblage within the poorly preserved interval includes *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, Helicosphaera euphratis, Pontosphaera spp., Sphenolithus moriformis* Group and *Zygrhablithus bijugatus*. These nannofossil assemblages are dominated by robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Sphenolithus moriformis* Group, making up to 95.4% of the total nannofossil assemblage. The dominance of these species suggests that the sediments in this part of the sampled section have undergone dissolution and/ or reworking during their depositional history. Further evidence that reworking has occurred is based upon the fact that *Sphenolithus radians* occurs in this part of the well section.

1. *Sphenolithus predistentus* Zone (IT4).

This zone is 58.5 metres (195 feet) thick and occurs within the Tarjil Formation between Sample Nos. K-85/ 3 and Sample No. K-85/ 10. The *Sphenolithus* *predistentus* Zone (IT4) is defined from the FDO of *Sphenolithus predistentus* to the FDO *Ericsonia subdisticha* and the nannofossil assemblages it contains are moderately to heavily overgrown (O-2.5) with secondary calcite and have very low to low abundance ratings (number of nannofossils per field of view ranges from 0.941 to 2.230). The nannofossil assemblage within the zone includes *Coccolithus pelagicus, Cyclicargolithus floridanus, Ericsonia obrupta, Helicosphaera compacta, H. euphratis, Pontosphaera spp., Reticulofenestra bisecta, R. scrippsae,* R. umbilica, Sphenolithus moriformis Group, S. predistentus and *Zygrhablithus bijugatus,* but the zone is dominated by the robust, solution resistant forms; *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, R. umbilica* and *Sphenolithus moriformis* Group which make up to 98.4% of the total nannofossil assemblage. This suggests that the sediments within the *Sphenolithus predistentus* Zone (IT4) have suffered from the effects of reworking and/ or dissolution during their depositional history. Further evidence that reworking has occurred within this zone is based upon the fact that *Sphenolithus radians* occurs within this zone, which must of been reworked from lower down in the section.

2. *Ericsonia subdisticha* Zone (IT5).

This zone occurs between Sample Nos. K-85/ 11 and K-85/ 23, and is 61.5 metres (205 feet) thick in this well section. The *Ericsonia subdisticha* Zone (IT5) samples the base of the Tarjil Formation and the Palani Formation but, this is probably a reworked occurrence as this zone is restricted to the Palani Formation in other well sections. The nannofossil assemblages making up this zone are moderately to heavily overgrown (O-2.5) with secondary calcite and have low abundance ratings (number of nannofossils per field of view ranging from 1.111 to 7.537). The nannofossil assemblages within the *Ericsonia subdisticha* Zone (IT5) is the same as the zone above with the addition of *Braarudosphaera bigelowii, Discoaster tanii, Ericsonia formosa, E. subdisticha, Rhabdolithus* spp., *R. tenuis,* and the exclusion of *Helicosphaera compacta.* The zone is also dominated by the robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Sphenolithus moriformis* Group, making up to 97 % of the total nannofossil assemblage. This suggests that the sediments within this zone have suffered from the effects of dissolution and/or reworking during their depositional history. The *Ericsonia subdisticha* Zone (IT5) also contains reworked examples of *Campylosphaera eodela, Reticulofenestra callida, Discoaster barbadiensis, Sphenolithus radians* and *Thoracosphaera operculata*, adding weight to the fact that reworking has occurred within this zone.

3. *Reticulofenestra dictyoda* Zone (IT6).

This zone occurs in the upper part of the Jaddala Formation between the Sample Nos. K-85/ 24 and K-85/ 29, and is 34.5 metres (115 feet) thick in this well section. The zone is defined from the FDO *Reticulofenestra dictyoda* to the FDO *Reticulofenestra callida*, and contains the same taxa as the zone above with the addition *Discoaster barbadiensis, Discoaster tanii nodifer, Helicosphaera compacta, Reticulofenestra dictyoda, Sphenolithus radians, and Traversopontis rectipons* and the exclusion of *Ericsonia subdisticha, Discoaster tanii,* and *Rhabdolithus tenuis*. The *Reticulofenestra dictyoda* Zone (IT6) is dominated by robust, solution resistant forms including *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae* and *Sphenolithus moriformis* Group which makes up to 84.9 % of the total nannofossil assemblage. This zone also contains reworked examples of *Thoracosphaera operculata* re-enforcing the fact that reworking has occurred during the deposition of the sediments making up this interval. There is also a number of caved ocurrences within the *Reticulofenestra dictyoda* Zone (IT6) including *Discoaster tanii, Ericsonia subdisticha* and *Helicosphaera euphratis*.

4. *Reticulofenestra callida* Zone (IT7).

This zone occurs in the base of the Jaddala Formation between Sample Nos. K-85/ 30 and K-85/ 37, and is 46.5 metres (155 feet) thick in this well section. The top of the *Reticulofenestra callida* Zone (IT6) is marked by the FDO of *Reticulofenestra callida* and the base of the zone is not reached before the total depth of the well section is reached. The zone is poorly preserved, possessing nannofossil assemblages that are moderately to heavily overgrown (O-2.5) with secondary calcite and have low abundance ratings (maximum number of nannofossils per field of view 4.208). The *Reticulofenestra callida* Zone (IT7) contains the same taxa as the zone above with the addition of *Reticulofenestra callida, Discoaster saipanensis, Nannotetrina fulgens,* and the exclusion of *Pontosphaera* spp., *Transversopontis rectipons* and *Helicosphaera compacta.* The zone also contains caved occurrences of *Discoaster tanii, Ericsonia subdisticha, Helicosphaera compacta* and *H. euphratis* and reworked examples of *Thoracosphaera operculata.*

Summary:

A summary diagram showing the location and the main points of information gathered from Kirkuk No. 85 during this study can be seen in Figure 6.8. The main points of information gathered from this well section are:

- 37 drill cutting samples taken from the lower part of the Tarjil Formation, the Palani Formation and the upper part of the Jaddala Formation.
- Overall the Kirkuk No. 85 well section is poorly preserved but despite this 4 zones can be defined in this well section:
    1. *Sphenolithus predistentus* Zone (IT4). Between Sample Nos. K-85/ 3 and K-85/ 10 from the Tarjil Formation.
    2. *Ericsonia subdisticha* Zone (IT5). Between Sample Nos. K-85/ 11 and K-85/ 23 from the Palani Formation.
    3. *Reticulofenestra dictyoda* Zone (IT6). Between Sample Nos. K-85/ 24 and K-85/ 29 from the upper part of the Jaddala Formation.
    4. *Reticulofenestra callida* Zone (IT7). Between Sample Nos. K-85 / 30 and K-85/ 37 also from the upper part of the Jaddala Formation.

6.3.8 Kirkuk No. 116. (See Kirkuk No. 116 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Kirkuk No. 116 well section occurs in northern Iraq, within the Kirkuk Oil Field, to the northeast of Kirkuk (Lat. 35 47' 29".00 N, Long. 43 59' 06".30 E). In all 23 samples were taken from the Kolosh Clastics and the Aaliji Formations, 20 of which were drill cuttings samples and 3 of which were conventional core samples. The nannofossil assemblages within this well section are slightly to heavily overgrown (O-1.5 to O-2.5) with secondary calcite and have abundance ratings ranging from low to

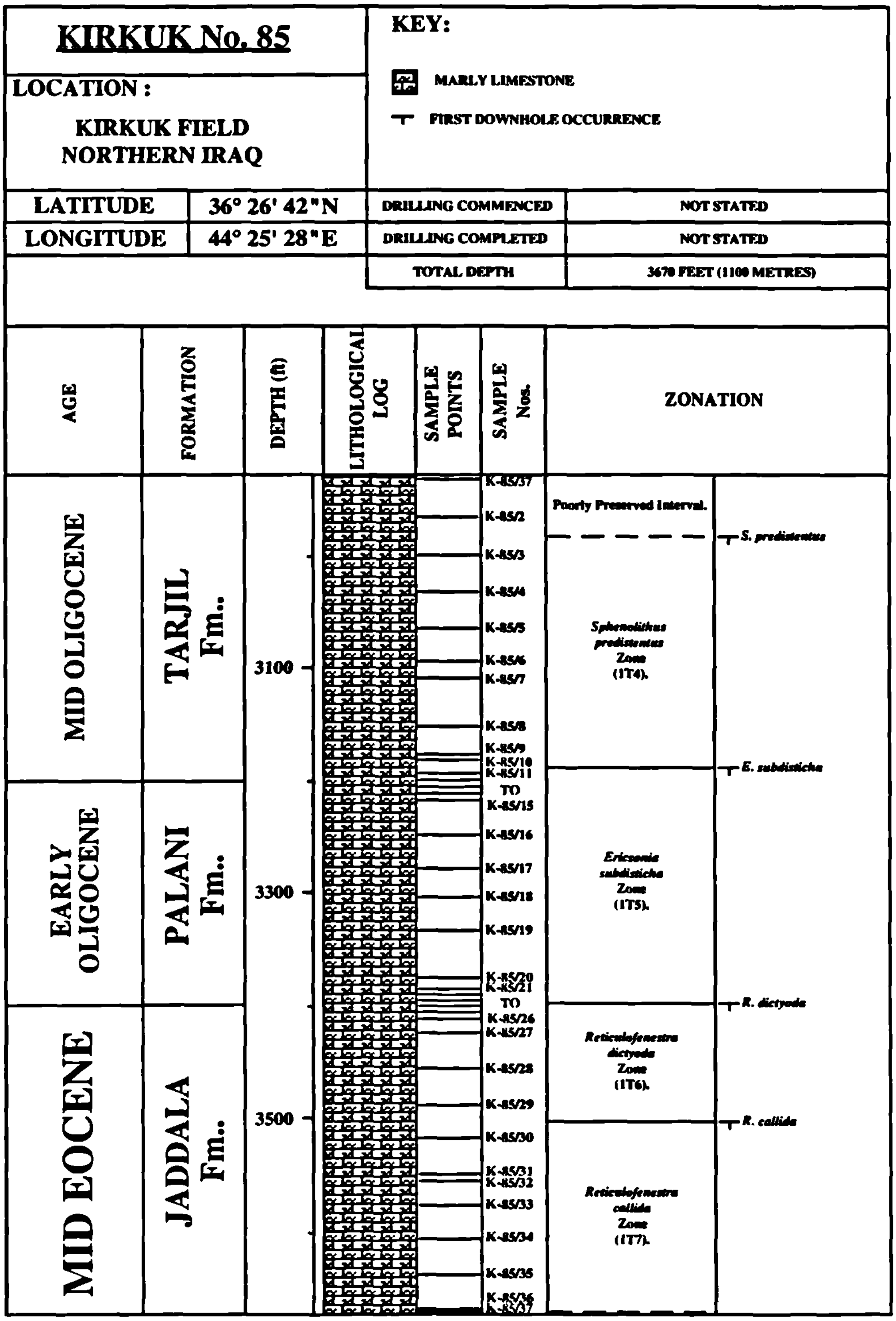


Figure 6. 8 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Kirkuk No. 85.

high (number of nannofossils per field of view ranges from 0.031 to 25.75). In all 6 zones and 2 subzones were defined in this section:

1. *Discoaster kuepperi* Zone (IT8): *Tribrachiatus orthostylus* Subzone (IT8c).
2. *Discoaster multiradiatus* (IT9).
3. *Fasciculithus tympaniformis* Zone (IT10): *Fasciculithus hayi* Subzone (IT10a).
4. *Heliolithus kleinpellii* Zone (IT11).
5. *Fasciculithus pileatus* Zone (IT12).
6. *Micula murus* Zone (IT13).

1. *Discoaster kuepperi* Zone (IT8): *Tribrachiatus orthostylus* Subzone (IT8c).

This subzone is located within the Kolosh Clastics Formation between Sample Nos. K-116/ 1 and K-116/ 4 is 13.5 metres (45 feet) thick in this well section. Only the base of the *Discoaster kuepperi* Zone (IT8) and the *Tribrachiatus orthostylus* Subzone (IT8c) is seen in this well section which is marked by the FDO of *Discoaster multiradiatus*. The nannofossil assemblage in this subzone is moderately to heavily overgrown (O-2.5) with secondary calcite and have very low abundance ratings (maximum number of nannofossils per field of view 0.031). The nannofossil assemblage in the *Tribrachiatus orthostylus* Subzone (IT8c) includes *Braarudosphaera bigelowii, Chiasmolithus consuetus, Coccolithus pelagicus, Discoaster kuepperi, D. barbadiensis, D. deflandrei, D. salisburgensis, Ericsonia formosa, Micrantholithus flos, Pontosphaera spp., Sphenolithus anarrhopus, S. editus, S. radians, S. moriformis* Group, *Thoracosphaera operculata, Tribrachiatus orthostylus* A, *T. orthostylus* B and *Zygrhablithus bijugatus*. The subzone contains quite large amounts of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up to 54% of the total nannofossil assemblages. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains *Chiasmolithus bidens, Cribrosphaerella ehrenbergii, Discoaster multiradiatus, Discoaster nobilis, Fasciculithus tympaniformis, Microrhabdulus undosus, Micula staurophora, Neochiastozygus distentus, Prediscosphaera cretacea, Prinsius bisulcus, P. dimorphosus, P. martini, Quadrum gartneri, Stradneria crenulata, Toweius eminens, Toweius tovae, Watznaueria barnesae* and *W. manivitae* which makes up to 24% of the total nannofossil assemblage. The *Tribrachiatus orthostylus* Zone (IT8c) also contains *Discoaster kuepperi, Reticulofenestra scrippsae, R. dictyoda, R. umbilica, Sphenolithus elongatus* and *S. furcatolithoides*, caved from above the sampled section within Kirkuk No. 116 well section.

2. *Discoaster multiradiatus* Zone (IT9).

This zone which occurs within the base of the Kolosh Clastics Formation in Sample No. K-116/ 5, and is 4.5 metres (15 feet) thick in this well section. The Discoaster multiradiatus Zone (IT9) is defined from the FDO of *Discoaster multiradiatus* to the FDO of *Fasciculithus tympaniformis*, and the nannofossil assemblage it contains is moderately to heavily overgrown (O-2.5) secondary calcite and has a very low abundance rating (number of nannofossils per field of view 0.785). The nannofossil assemblage within this zone includes *Braarudosphaera bigelowii, Chiasmolithus bidens, Coccolithus pelagicus, Discoaster lodoensis, D. multiradiatus, Ericsonia robusta, Neochiastozygus distentus, Prinsius bisulcus, Sphenolithus anarrhopus, S. moriformis* Group, *S. radians, Thoracosphaera operculata* and *Toweius eminens*. The *Discoaster multiradiatus* Zone (IT9) also contains quite high amounts of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up to 95% of the total nannofossil assemblage. The zone also contains caved *Discoaster kuepperi* and reworked *Eiffellithus gorkae, Watznaueria barnesae* and *W. manivitae* but only making up approximately 1% of the total nannofossil assemblage.

3. *Fasciculithus tympaniformis* Zone (IT10): *Fasciculithus hayi* Subzone (IT10a).

This zone occurs within the Aaliji Formation between Sample Nos. K-116/ 6 and K-116/ 18 and is 37.5 metres (125 feet) thick in this well section. The *Fasciculithus tympaniformis* Zone (IT10) is defined from the FDO of *Fasciculithus tympaniformis* to the FDO of *Heliolithus kleinpellii*. The *Fasciculithus tympaniformis* Zone (IT10) has been divided in this well section based on the acme occurrence of *Fasciculithus hayi* at the top of the zone. The *Fasciculithus hayi* Subzone (IT10a) occurs between Sample Nos. K-116/ 6 and K-116/ 10, and is 13.5 metres (45 feet) thick in this well section. The nannofossil assemblages making up this subzone are mainly moderately to heavily overgrown (O-2.5) with secondary calcite except for Sample No. K-116 / 11 which is moderately overgrown (O-2) with secondary calcite. The nannofossil assemblages within the *Fasciculithus hayi* Subzone (IT10a) also have low to high abundance ratings (number of nannofossils per field of view 1.431 to 25.75) and contains *Campylosphaera eodela, Chiasmolithus bidens, C. consuetus, Coccolithus pelagicus, Cruciplacolithus tenuis, Discoaster mohleri, D. multiradiatus, Ellipsolithus macellus, Ericsonia robusta, Fasciculithus alanii, F. hayi, F. involutus, F. thomasii, F. tympaniformis, Markalius inversus, Neochiastozygus distentus, Prinsius bisulcus, P. martini, Scapholithus rhombiformis, Sphenolithus anarrhopus, S. moriformis* Group, *Thoracosphaera operculata, Toweius eminens* and *T. tovae*. This part of the well section is dominated by *Coccolithus pelagicus, Ericsonia robusta, Fasciculithus* spp., *Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up to 91.7 % of the total nannofossil assemblage. The *Fasciculithus hayi* Subzone also contains reworked Cretaceous and Mid Palaeocene taxa including *Chiastozygus litterarius, Cribrosphaerella ehrenbergii, Eiffellithus turriseiffelii, Fasciculithus bitectus, Quadrum gartneri, Q. gothicum, Micula murus, M. staurophora, Prediscosphaera cretacea, P. grandis, Prinsius dimorphosus, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae* making up approximately 5% of the total nannofossil assemblage. The well section also contains caved examples of *Discoaster kuepperi, Ericsonia formosa, Sphenolithus radians* and *Zygrhablithus bijugatus*.

Below the *Fasciculithus hayi* Subzone (IT10a), the *Fasciculithus tympaniformis* Zone (IT10) contains nannofossil assemblages that are slightly to moderately overgrown (O-1.5) with secondary calcite and have low to high abundance ratings (number of nannofossils per field of view 2.849 to 20.6). This part of the *Fasciculithus tympaniformis* Zone (IT10) contains the same species as the *Fasciculithus hayi* Subzone with the exception of *Fasciculithus alanii*, and the addition of *Discoaster nobilis, Lophodolithus nacens, Neochiastozygus junctus, Placozygus sigmoides* and *Zygodiscus bramlettei*. This part of the zone is again dominated by a similar group of species as the *Fasciculithus hayi* Subzone (IT10a) including *Coccolithus pelagicus, Fasciculithus tympaniformis, Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera* *operculata* and *Toweius* spp., making approximately 95% of the total nannofossil assemblage. The *Fasciculithus tympaniformis* Zone (IT10) in this part of the well section also contains a number of reworked Cretaceous and Mid Palaeocene species including *Arkhangelskiella cymbiformis, Eiffellithus gorkae, Ellipsolithus distichus, Fasciculithus bitectus, F. janii, Quadrum gartneri, Microrhabdulus undosus, Micula staurophora, Prediscosphaera cretacea, Prinsius dimorphosus, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae* making up approximately 5% of the total nannofossil assemblage. The zone in this part of the well section also contains caved examples of *Discoaster kuepperi, D. barbadiensis, Ericsonia formosa, Sphenolithus radians, Tribrachiatus orthostylus* A and *Zygrhablithus bijugatus*.

4. *Heliolithus kleinpellii* Zone (IT11).

This zone occurs in the lower part of the Aaliji Formation between Sample Nos. K-116/ 19 and K-116/ 21 and is 12 metres (40 feet) thick in this well section. The *Heliolithus kleinpellii* Zone (IT11) is defined from the FDO *Heliolithus kleinpellii* to the FDO *Fasciculithus pileatus*. The nannofossil assemblages within the zone are slightly to moderately overgrown (O-1.5 to O-2) with secondary calcite and have low to moderate abundance ratings (number of nannofossils per field of view 6.977 to 12). The *Heliolithus kleinpellii* Zone (IT11) contains the same taxa as the zone above with the addition of *Ellipsolithus distichus, Heliolithus kleinpellii*, but excluding *Campylosphaera eodela, Chiasmolithus consuetus, Discoaster nobilis, Fasciculithus hayi, F. involutus, F. thomasii, Lophodolithus nacens, Neochiastozygus distentus*, and *Placozygus sigmoides*. The zone is dominated by *Coccolithus pelagicus, Fasciculithus tympaniformis, Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up approximately 95% of the total nannofossil assemblage. The *Heliolithus kleinpellii* Zone (IT11) also contains reworked Cretaceous and Mid Palaeocene taxa including *Eiffellithus gorkae, Fasciculithus bitectus, Microrhabdulus undosus, Neochiastozygus modestus, Stradneria crenulata* and *Watznaueria barnesae* making up approximately 1% of the total nannofossil assemblage. The *Heliolithus kleinpellii* Zone (IT11) is believed to extend from NP6/ CP5 to lowermost part of NP9/ CP8a however, *Discoaster multiradiatus* and *Toweius eminens* occur throughout the zone in this well section, while this not true of the other well sections containing this zone. Therefore, it is believed that the lower part of the ranges of these taxa are caved, but this has not been highlighted on the distribution diagram for Kirkuk No. 116 as the caved portion of the range cannot be accurately identified. The *Heliolithus kleinpellii* Zone (IT11) also contains *Ericsonia formosa* believed to be caved from higher in the well section.

5. *Fasciculithus pileatus* Zone (IT12).

The zone occurs in Sample No. K-116/ 22, toward the base of the Aaliji Formation and is 19.5 metres (65 feet) thick in this well section. The *Fasciculithus pileatus* Zone (IT12) is defined from the FDO of *Fasciculithus pileatus* to the FDO of *Micula murus* and other Cretaceous taxa. The nannofossil assemblage within this zone is moderately overgrown (O-2) with secondary calcite and has a low abundance rating (number of nannofossils per field of view 8.108). The nannofossil assemblage within the *Fasciculithus pileatus* Zone (IT12) contains *Chiasmolithus bidens, Coccolithus pelagicus, Cruciplacolithus tenuis, Ericsonia robusta, Fasciculithus bitectus, F. janii, F. pileatus, F. tympaniformis, Neochiastozygus modestus, Prinsius bisulcus, Scapholithus rhombiformis, Sphenolithus moriformis* Group, *Thoracosphaera operculata* and *Zygodiscus bramlettei.* The zone is dominated by *Coccolithus pelagicus, Fasciculithus tympaniformis, Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up approximately 97% of the total nannofossil assemblage. The *Fasciculithus pileatus* Zone (IT12) also contains reworked Cretaceous taxa including *Microrhabdulus undosus, Prediscosphaera cretacea, P. grandis* and *Watznaueria barnesae* making up approximately 1% of the total nannofossil assemblage. The zone also contains caved taxa including *Ericsonia formosa, Heliolithus kleinpellii, Neochiastozygus junctus, Toweius eminens* and *T. tovae.*

13. *Micula murus* Zone (IT13).

This zone occurs in the Shiranish Formation in Sample No. K-116/ 23, which is taken from well below the boundary between the Aaliji Formation and the Shiranish

Formation as no other samples were available for collection in this well section. The top of the *Micula murus* Zone (IT13) is defined from the FDO of *Micula murus* but, the base of the zone is not encountered in this sampled section of this well section. The nannofossil assemblage in this zone is moderately overgrown (O-2) with secondary calcite and has a low abundance rating (number of nannofossils per field of view 7.143). The *Micula murus* Zone (IT13) contains *Arkhangelskiella cymbiformis, Chiastozygus amphipons, C. litterarius, Cribrosphaerella ehrenbergii, Eiffellithus gorkae, E. turriseiffelii, Gartnerago obliquum, Helicolithus trabeculatus, Lithraphidites spp., Markalius apertus, Microrhabdulus undosus, Micula murus, M. staurophora, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis, P. stoveri, Quadrum gartneri, Q. gothicum, Stradneria crenulata, Thoracosphaera operculata, Tranolithus minimus, Watznaueria barnesae* and *W. manivitae*. The zone also contains caved taxa; *Coccolithus pelagicus, Ellipsolithus macellus, Ericsonia robusta, Fasciculithus tympaniformis, Prinsius bisulcus, Sphenolithus anarrhopus, Sphenolithus moriformis* Group and *Toweius eminens*.

Summary:

A summary diagram showing the location and the main points of information gathered from Kirkuk No. 116 during this study can be seen Figure 6.9. The main points of information gathered from this well section are:

- 20 drill cutting and 3 conventional core samples taken from the lower part of the Kolosh Clastics Formation, the Aaliji Formation and the upper part of the Shiranish Formation.
- Overall the Kirkuk No. 116 well section is moderately well preserved and 6 zones and 2 Subzones can be defined in this well section:

  1. *Discoaster kuepperi* Zone (IT8): *Tribrachiatus orthostylus* Subzone (IT8a). Between Sample Nos. K-116/ 1 and K-116/ 4 from the Kolosh Clastics Formation.
  2. *Discoaster multiradiatus* Zone (IT9). Sample No. K-116/ 5 Aaliji Formation.
  3. *Fasciculithus tympaniformis* Zone (IT10): *Fasciculithus hayi* Subzone (IT10a). Between Sample Nos. K-116/ 6 and K-116/ 18 (to Sample No. K-116/ 10 for the *Fasciculithus hayi* Zone) from the upper part of the Aaliji Formation.
  4. *Heliolithus kleinpellii* Zone (IT11). Between Sample Nos. K-116/ 19 and K-116/ 21 from the Aaliji Formation.

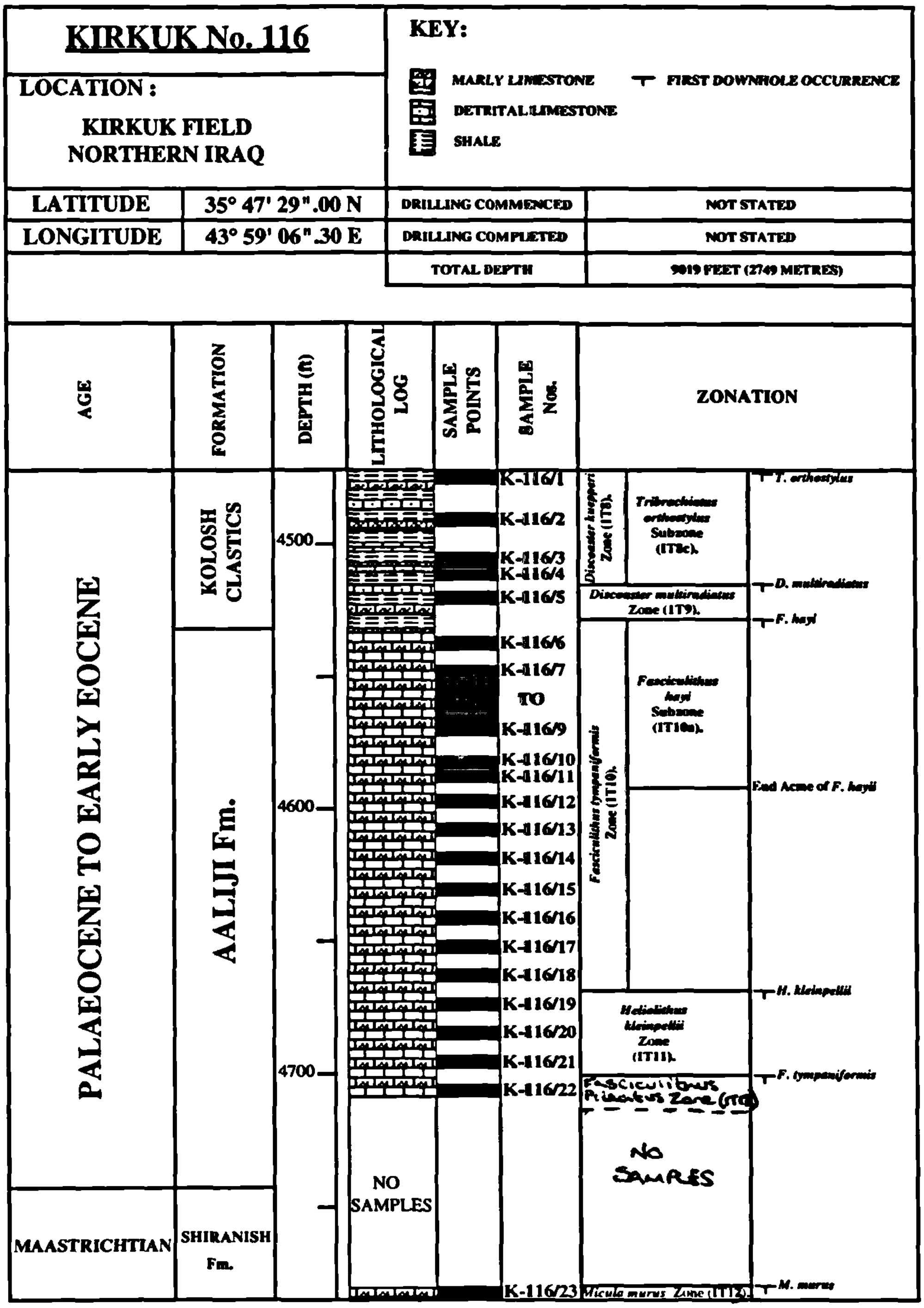


Figure 6. 9 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Kirkuk No. 116.

5. *Fasciculithus pileatus* Zone (IT12). Sample No. K-116/ 22 from the Aaliji Formation.

6. *Micula murus* Zone (IT13). Sample No. K-116/ 23 from the base of the Shiranish Formation.

6.3.9 Pulkhana No. 5. (See Pulkhana No. 5 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Pulkhana No. 5 well section is located in northern Iraq, to the southeast of Kirkuk (Lat. 34° 47' 58".80 N, Long. 44° 46' 58".8 E). In all 46 samples comprising 37 conventional core and 9 drill cutting samples, were taken from the Serikagni, Jaddala, Aaliji and Shiranish Formations. In this well section it has been possible to define 9 zones spanning the Late Cretaceous to Early Oligocene:

1. *Reticulofenestra bisecta* Zone (IT2).
2. *Ericsonia subdisticha* Zone (IT5).
3. *Reticulofenestra dictyoda* Zone (IT6).
4. *Reticulofenestra callida* Zone (IT7).
5. *Discoaster kuepperi* Zone (IT8).
6. *Fasciculithus tympaniformis* Zone (IT10).
7. *Heliolithus kleinpellii* Zone (IT11).
8. *Fasciculithus pileatus* Zone (IT12).
9. *Micula murus* Zone (IT13).

These zones are now discussed below in descending stratigraphic order.

1. *Reticulofenestra bisecta* Zone (IT2).

This zone occurs at the top of the sampled section within the lower part of the Serikagni Formation in Sample No. Pu-5/ 1 and is at least 1.5 metres (5 feet) thick in this well section. The nannofossil assemblage within the *Reticulofenestra bisecta* Zone (IT2) is moderately overgrown (O-2) with secondary calcite and has a low abundance rating (number of nannofossils per field of view 4.079). The top of this zone is seen in this section but the base of the zone is marked by the FDO of *Ericsonia subdisticha*. The nannofossil assemblage within the *Reticulofenestra bisecta* Zone (IT2) includes *Braarudosphaera bigelowii, Cyclicargolithus abisectus, C. floridanus, Discoaster deflandrei, Helicosphaera euphratis, Pontosphaera spp., Reticulofenestra bisecta, R. scrippsae, Sphenolithus dissimilis, S. moriformis* Group and *Zygrhablithus bijugatus*. The zone is dominated by *Coccolithus pelagicus*, *Cyclicargolithus abisectus, C. floridanus, Reticulofenestra bisecta, R. scrippsae, Sphenolithus moriformis* Group and *Zygrhablithus bijugatus* making up approximately 97% of the total nannofossil assemblage. These species are robust solution resistant forms and indicate that the sediments within the zone have suffered the effects of dissolution and/ or reworking during their depositional history. This evidence is supported by the fact that *Helicosphaera compacta* occurs within zone reworked from lower down in the well section. The *Reticulofenestra bisecta* Zone (IT2) also contains *Helicosphaera kamptneri* caved from above the sampled interval within the well section.

2. *Ericsonia subdisticha* Zone (IT5).

This zone occurs within the Jaddala Formation between Sample Nos. Pu-5/ 2 and Pu-5/ 13 and is 92 metres (307 feet) thick in this well section. However, the *Ericsonia subdisticha* Zone (IT5) has been associated with the younger Palani Formation in this study and therefore it seems the lithostratigraphy is incorrect and the Palani Formation has been sampled, which has a similar globigerinid, marly limestone lithology as the Jaddala Formation. This same problem was encountered earlier in the Jambur No. 4 well section, which is situated only 40 kilometres northeast of Pulkhana No. 5. The *Ericsonia subdisticha* Zone (IT5) is defined from the FDO of *Ericsonia subdisticha* to the FDO *Reticulofenestra dictyoda* in this well section, and the nannofossil assemblages it contains are slightly to moderately overgrown (O-1.5 to O-2) with secondary calcite and have low to very high abundance ratings (number of nannofossils per field of view ranges from 3.367 to 34). The nannofossil assemblages within this zone are the same as the zone above with the addition of *Coccolithus pelagicus, Discoaster tanii, D. tanii nodifer, Ericsonia formosa, E. obrupta, E. subdisticha, Helicosphaera wilcoxonii, Micrantholithus flos, Pontosphaera multipora, Pyrocyclus hermosus, Rhabdolithus spp., Reticulofenestra minuta, R. umbilica, Sphenolithus moriformis, S. predistentus*, and the exclusion of *Sphenolithus dissimilis*. The zone is dominated by *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, Sphenolithus moriformis* Group and *Zygrhablithus bijugatus* making up approximately 97% of the total nannofossil assemblage. This dominance of robust and solution resistant forms may indicate that the sediments within the zone may have suffered from the effects of reworking and/or dissolution during their depositional history. This evidence is backed up by the fact that *Reticulofenestra dictyoda, Sphenolithus anarrhopus, S. radians* and *Thoracosphaera operculata are reworked into this zone.*

3. *Reticulofenestra dictyoda* Zone (IT6).

This zone is 91 metres (302 feet) thick and occurs between Sample Nos. Pu-5/ 14 to Pu-5/ 24, within the Jaddala Formation. The *Reticulofenestra dictyoda* Zone (IT6) is defined from the FDO of *Reticulofenestra dictyoda* to the FDO of *Reticulofenestra callida* and the nannofossil assemblages it contains are slightly to heavily overgrown (O-1.5 to O-2.5) with secondary calcite and have low to high abundance ratings (number of nannofossils per field of view ranges from 7.143 to 20.4). The nannofossil assemblages within the *Reticulofenestra dictyoda* Zone (IT6) contains the same taxa as the zone above with the addition of *Markalius inversus, Reticulofenestra dictyoda, Sphenolithus radians,* and the exclusion of *Discoaster deflandrei, Ericsonia subdisticha, Pontosphaera multipora, Pyrocyclus hermosus, Reticulofenestra minuta* and *Sphenolithus moriformis.* The *Reticulofenestra dictyoda* Zone (IT6) is dominated by *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, Sphenolithus moriformis* Group, *S. predistentus, S. radians* and *Zygrhablithus bijugatus* making up approximately 97% of the total nannofossil assemblage. These species are robust and solution resistant forms and may indicate that the sediments within the zone have suffered from the effects of reworking and/ or dissolution during their depositional history. This evidence is backed up by the fact that the zone also contains reworked examples of *Cruciplacolithus latipons, Reticulofenestra callida, Nannoterina fulgens* and *Scapholithus rhombiformis.*

4. *Reticulofenestra callida* Zone (IT7).

This zone is recognised within the Jaddala Formation between Sample Nos. Pu-5/ 25 and Pu-5/ 34 and is 82 metres (274 feet) thick in this well section. This *Reticulofenestra callida* Zone is defined from the FDO of *Reticulofenestra callida* to the FDO of *Discoaster kuepperi* in this well section and contains nannofossil assemblages that are moderately to heavily overgrown (O-2.5) and have low abundance ratings (maximum number of nannofossils per field of view 8.722). The nannofossil assemblages within this zone are the same as the zone above with the addition of *Chiasmolithus consuetus, C. grandis, Reticulofenestra callida, Discoaster barbadiensis, D. saipanensis, Nannotetrina fulgens, Sphenolithus furcatolithoides, S. spiniger*, and the exclusion of *Braarudosphaera bigelowii, Helicosphaera compacta, Micrantholithus flos* and *Pontosphaera* spp.. The *Reticulofenestra callida* Zone (IT7) is dominated by *Coccolithus pelagicus, Cyclicargolithus floridanus, Reticulofenestra bisecta, R. scrippsae, Sphenolithus moriformis* Group, *Sphenolithus predistentus, Sphenolithus radians* and *Zygrhablithus bijugatus* making up approximately 90% of the total nannofossil assemblage. These species are robust and solution resistant forms and may indicate that the sediments within the zone have suffered from the effects of reworking and/ or dissolution during their depositional history. This evidence is backed up by the fact that the zone also contains reworked examples of *Campylosphaera eodela, Chiasmolithus bidens* and Discoaster kuepperi. The *Reticulofenestra callida* Zone (IT7) also contains caved examples of *Ericsonia subdisticha.*

5. *Discoaster kuepperi* Zone (IT8).

This zone occurs in the upper part of the Aaliji Formation between Sample No. Pu-5/ 35 and Pu-5/ 36 and is 11 metres (36 feet) thick in this well section. The *Discoaster kuepperi* Zone (IT8) is defined from the FDO of *Discoaster kuepperi* to the FDO of *Fasciculithus tympaniformis*. In other well sections, this zone has been subdivided into three subzones and has the *Discoaster multiradiatus* Zone (IT9) below it. However, these subdivisions of the *Discoaster kuepperi* Zone and the recognition of the *Discoaster multiradiatus* Zone (IT9) cannot be made in this case as this part of the well section is condensed. The nannofossil assemblages in the *Discoaster kuepperi* Zone (IT8) are moderately to heavily overgrown (O-2 and O-2.5) with secondary calcite and have low abundance ratings (maximum number of nannofossils per field of view is 3.188). The nannofossil assemblage recorded in this zone includes

Braarudosphaera bigelowii, Campylosphaera eodela, Chiasmolithus bidens, C. consuetus, Coccolithus pelagicus, Discoaster barbadiensis, D. deflandrei, D. kuepperi, D. lodoensis, D. mahmoudii, D. saipanensis, Ericsonia formosa, Markalius inversus, Micrantholithus flos, Reticulofenestra dictyoda, Sphenolithus moriformis Group, S. radians, Tribrachiatus orthostylus B and Zygrhablithus bijugatus. The *Reticulofenestra callida* Zone (IT7) is dominated by *Coccolithus pelagicus, Sphenolithus moriformis* Group, *S. radians* and *Zygrhablithus bijugatus* making up approximately 90% of the total nannofossil assemblage. These species are robust and solution resistant forms and may indicate that the sediments within the zone have suffered from the effects of reworking and/ or dissolution during their depositional history. This evidence is backed up by the fact that the zone also contains reworked examples *Cruciplacolithus latipons* and *Discoaster mohleri.*

6. *Fasciculithus tympaniformis* Zone (IT10).

This zone occurs within the Aaliji Formation between Sample Nos. Pu-5/ 37 and Pu-5/ 39 and is 23 metres (77 feet) thick in this well section. The *Fasciculithus tympaniformis* Zone (IT10) is defined from the FDO *Fasciculithus tympaniformis* to the FDO of *Heliolithus kleinpellii*, and is split up in other well sections based upon the acme occurrence of *Fasciculithus hayi.* This is not possible in this well section as *Fasciculithus hayi* is not recorded and possibly due to the condensed nature of this part of the well section. The nannofossil assemblages within the *Fasciculithus tympaniformis* Zone (IT10) are moderately to heavily overgrown (O-2 to O-2.5) with secondary calcite and have very low to low abundance ratings (number of nannofossils per field of view ranges from 0.856 to 3.483). The nannofossil assemblages within this zone include *Braarudosphaera bigelowii, Chiasmolithus bidens, Coccolithus pelagicus, Cruciplacolithus tenuis, Ellipsolithus macellus, E. distichus, Ericsonia robusta, Fasciculithus tympaniformis, Neochiastozygus distentus, Prinsius bisulcus, P. martini, Scapholithus rhombiformis, Sphenolithus anarrhopus, S. moriformis* Group, *Thoracosphaera operculata, Toweius eminens, T. tovae* and *Zygrhablithus bijugatus.* The *Fasciculithus tympaniformis* Zone (IT10) is dominated by *Coccolithus pelagicus, Sphenolithus moriformis* Group, *S. radians* and *Zygrhablithus bijugatus* making up approximately 90% of the total nannofossil assemblage. These species are robust and solution resistant forms and may indicate that the sediments within the zone have suffered from the effects of reworking and/ or dissolution during their depositional history. This evidence is backed up by the fact that reworking has occurred in this zone as it contains Cretaceous and Mid Palaeocene taxa including *Cribrosphaerella ehrenbergii, Eiffellithus gorkae, Heliolithus kleinpellii, Markalius apertus, Microrhabdulus decoratus, Micula staurophora, Prinsius dimorphosus, Quadrum gothicum, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae*. This zone also shows an increase in caved occurrences associated with two drill cutting samples, Sample Nos. Pu-5/ 37 and Pu-5/ 38). The caved taxa include *Cyclicargolithus floridanus, Discoaster deflandrei, D. barbadiensis, D. kuepperi, Ericsonia formosa, E. obrupta, Reticulofenestra bisecta, R. callida, R. scrippsae,* R. umbilica, Rhabdolithus spp., *Sphenolithus furcatolithoides, S. radians, S. spiniger* and *Zygrhablithus bijugatus*.

7. *Heliolithus kleinpellii* Zone (IT11).

This zone occurs within the Aaliji Formation between Sample Nos. Pu-5/ 40 and Pu-5/ 41 and is 7 metres (22 feet) thick in this well section. The *Heliolithus kleinpellii* Zone (IT11) is defined from the FDO of *Heliolithus kleinpellii* to the FDO *Fasciculithus pileatus* and the nannofossil assemblages it contains are slightly to moderately overgrown (O-1.5 to O-2) with secondary calcite. The two samples making up this zone have widely differing abundance ratings Sample No. Pu-5/ 40 has a moderate abundance rating (number of nannofossils per field of view, 15), while Sample No. Pu-5/ 41 has a very low abundance (number of nannofossils per field of view, 0.221). This *Heliolithus kleinpellii* Zone (IT11) contains the same taxa as the zone above with the addition of *Heliolithus kleinpellii, Markalius apertus, M. inversus,* and *Placozygus sigmoides,* but excludes *Braarudosphaera bigelowii, Ellipsolithus distichus, Neochiastozygus distentus* and *Scapholithus rhombiformis*. This zone also contains reworked taxa again mainly from the Cretaceous including *Calculites ovalis, Cribrosphaerella ehrenbergii, Eiffellithus eximius, Microrhabdulus decoratus, Micula staurophora, Neochiastozygus modestus, Prediscosphaera cretacea, Prinsius* *dimorphosus, Quadrum gartneri, Q. gothicum, Q. trifidum, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae*. This *Heliolithus kleinpellii* Zone (IT11) also contains several caved taxa from higher up in the well section, these include *Reticulofenestra bisecta, Ericsonia obrupta* and *Sphenolithus moriformis*.

8. *Fasciculithus pileatus* Zone (IT12).

This zone occurs in the base of the Aaliji Formation between Sample Nos. Pu-5/ 42 and Pu-5/ 45 and is 29 metres (95 feet) thick in this well section. The *Fasciculithus pileatus* Zone (IT12) is defined from the FDO *Fasciculithus pileatus* to the FDO *Micula murus*, and the nannofossil assemblages it contains is moderately to heavily overgrown (O-2 to O-2.5) with secondary calcite, that have very low abundance ratings (maximum number of nannofossils per field of view 0.19). The nannofossil assemblage in the Fasciculithus pileatus Zone (IT12) is the same as the zone above with the addition of *Fasciculithus pileatus* and *Neochiastozygus modestus, but excluding Ellipsolithus macellus, Markalius apertus, Placozygus sigmoides, Toweius eminens, and T. tovae*. The Sample No. Pu-5/ 45 in the base of this zone marks a heavily reworked horizon and is dominated robust, solution resistant species including *Micula staurophora* and *Watznaueria barnesae* making up 92% of the total assemblage. This suggests that this part of the section has undergone the effects of dissolution and/ or reworking during its depositional history and may reflect the hiatus between the Mid Palaeocene and the Late Cretaceous in this well section. The *Fasciculithus pileatus* Zone (IT12) also contains reworked taxa mainly from the Cretaceous and include *Arkhangelskiella cymbiformis, Calculites ovalis, Cribrosphaerella ehrenbergii, Gartnerago obliquum, Lithraphidites spp., Microrhabdulus decoratus, M. undosus, Micula murus, M. staurophora, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis, Quadrum gartneri, Q. gothicum, Q. trifidum, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae*. This zone also contains caved examples of *Reticulofenestra scrippsae, Fasciculithus schaubii, Heliolithus kleinpellii* and *Toweius tovae*.

5. *Micula murus* Zone (IT13).

This zone occurs within the Shiranish Formation in Sample No. Pu-5/ 46 and is at least 1.5 metres (5 feet) thick in this section. The top of the *Micula murus* Zone (IT13) is marked by the FDO *Micula murus* and the base of this zone is not reached in this well section. The nannofossil assemblage in the *Micula murus* Zone (IT13) is moderately to heavily overgrown (O-2.5) with secondary calcite and has a very low abundance rating (number of nannofossils per field of view 0.19). This nannofossil assemblage recorded in this zone includes *Arkhangelskiella cymbiformis, Ceratolithoides kamptneri, Chiastozygus amphipons, C. litterarius, Cribrosphaerella ehrenbergii, Eiffellithus gorkae, E. turriseiffelii, Gartnerago obliquum, Lithraphidites spp., Microrhabdulus decoratus, M. undosus, Micula murus, M. staurophora, Placozygus fibuliformis, Prediscosphaera cretacea, P. grandis, P. stoveri, Quadrum gartneri, Q. gothicum, Q. trifidum, Stradneria crenulata, Thoracosphaera operculata, Watznaueria barnesae* and *W. manivitae.*

Summary:

A summary diagram showing the location and the main points of information gathered from Pulkhana No. 5 during this study can be seen figure 6.10. The main points of information gathered from this well section are:

- 37 conventional core and 9 drill cutting samples taken from the Serikagni, Palani, Jaddala, Aaliji and the upper part of the Shiranish Formations.
- Overall the Pulkhana No. 5 well section is moderately well preserved and 6 zones and 2 Subzones can be defined in this well section:

  1. *Reticulofenestra bisecta* Zone (IT2). Sample No. Pu-5/ 1 from the Serikagni Formation.
  2. *Ericsonia subdisticha* Zone (IT5). Between Sample Nos. Pu-5/ 2 and Pu-5/ 13 from the Palani Formation.
  3. *Reticulofenestra dictyoda* Zone (IT6). Between Sample Nos. Pu-5/ 14 and Pu-5/ 24 from the Jaddala Formation.
  4. *Reticulofenestra callida* Zone (IT7). Between Sample Nos. Pu-5/ 25 and Pu-5/ 34 from the Jaddala Formation.
  5. *Discoaster kuepperi* Zone (IT8). Between Sample Nos. Pu-5/ 35 and Pu-5/ 36 from the Aaliji Formation.

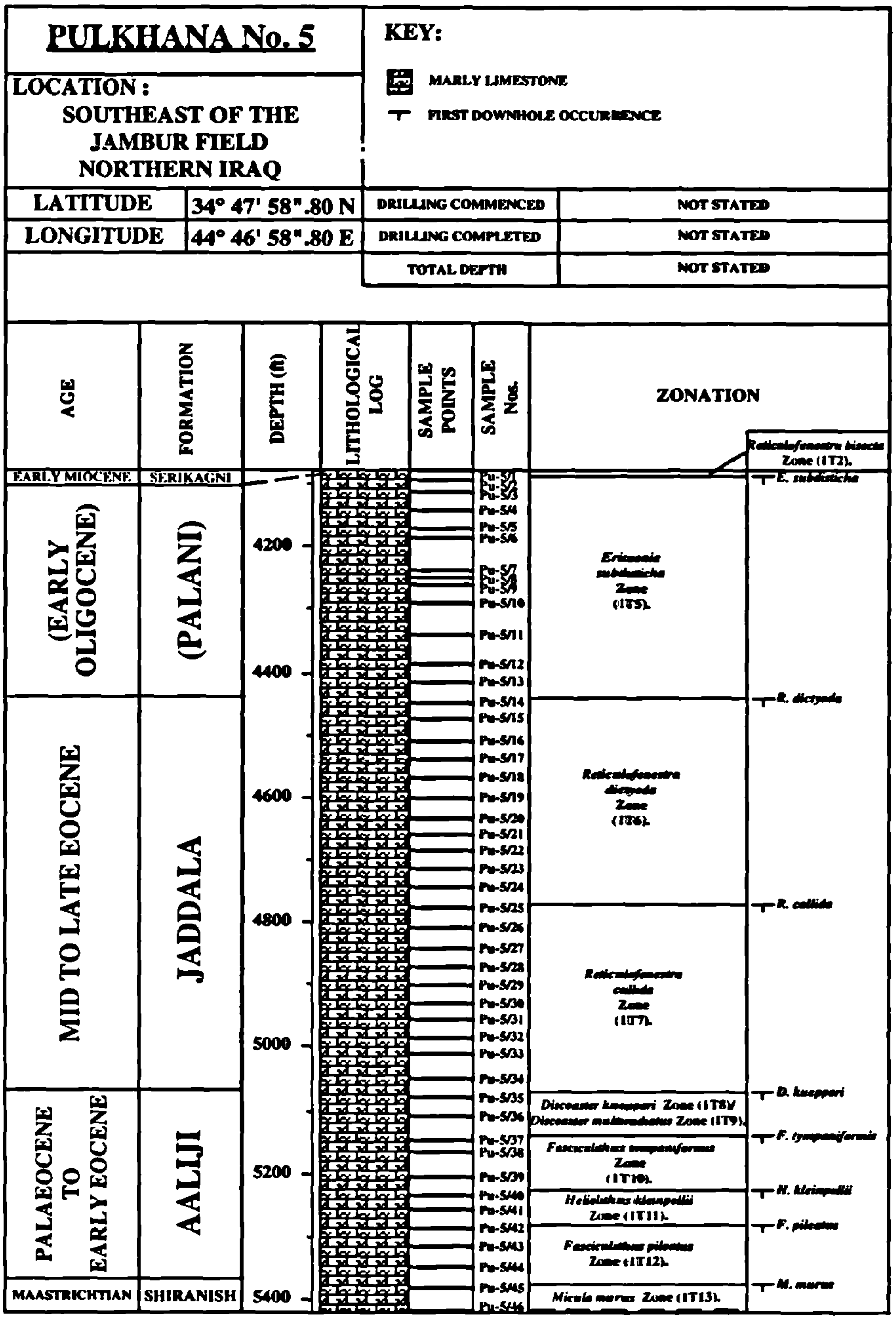


Figure 6.10 Summary Diagram of the Main Biostratigraphic Information from I.P.C. Well Pulkhana No. 5.

6. *Fasciculithus tympaniformis* Zone (IT10). Between Sample Nos. Pu-5/ 37 and Pu-5/ 39 from the Aaliji Formation.

7. *Heliolithus kleinpellii* Zone (IT11). Sample Nos. Pu-5/ 40 and Pu-5/ 41 from the Aaliji Formation.

8. *Fasciculithus pileatus* Zone (IT12). Between Sample Nos. Pu-5/ 42 and Pu-5/ 45 from the Aaliji Formation.

9. *Micula murus* Zone (IT13). Sample No. Pu-5/ 46 from the Shiranish Formation.

- Finally, a high percentage of reworked taxa was noted at the boundary between the Late Cretaceous and the Mid Palaeocene.

6.3.10 Chemchemal No. 2. (See Chemchemal No. 2 Well Log, Data Sheet, Range Chart and Abundance Diagram in Appendix A).

The Chemchemal No. 2 occurs to the west of Kirkuk in northern Iraq. In all 133 drill cutting samples were taken from the Lower Fars (Transition Beds), Pila Spi Limestone, Gercüş Red Beds, Khurmala Limestone, Sinjar Limestone and the Aaliji/ Kolosh Clastics Formations. The section has two intervals that yielded nannofossils. These are Sample Nos. Ch-2/ 1 to Ch-2/ 3 from the Lower Fars (Transition Beds) and the uppermost part of the Pila Spi Limestone Formations, and Ch-2/ 45 to Ch-2/ 134 from the lower part of the Sinjar Limestone and from the Aaliji/ Kolosh Clastics Formations. Overall the nannofossil assemblage in this section is slightly to moderately overgrown (O-0.5 to O-2), and has a very low to moderate abundance rating (number of nannofossils per field of view ranges from 0.002 to 16.778).

The barren interval between these two intervals that yielded nannofossils samples most of the Pila Spi Limestone, Gercüş Red Beds, Khurmala Limestone and the uppermost part of the Sinjar Limestone Formations. This part of the section is probably barren of nannofossils as the sediments were deposited in environments not generally exploited by calcareous nannoplankton. The Pila Spi Limestone Formation comprises nummulitic limestones, the Gercüş Red Beds Formation comprises red marls and conglomerate beds believed to form part of distal facies of an alluvial fan deposited on a coastal plain, the Khurmala Limestone Formation is heavily recrystallised and is dolomitic and contains no recognisable fauna, and finally the top of the Sinjar

Limestone Formation contains nummulitic limestones but becomes interbedded with soft blue and brown marls and shales at the point at which it yields nannofossils.

The top of the well section between Sample Nos. Ch-2/ 1 and Ch-2/ 3, is poorly preserved and it is believed that samples Ch-2/ 2 and Ch-2/ 3 contains a caved nannofossils from Ch-2/ 1, including the reworked taxa from lower down the well section. The nannofossil assemblage in this part of the well section is slightly to moderately overgrown (O-1.5), and has a very low abundance rating (maximum number of nannofossils per field of view 0.242). The nannofossil assemblage includes *Coccolithus pelagicus, Cyclicargolithus floridanus, Discoaster deflandrei, D. variabilis, Ericsonia obrupta, Helicosphaera euphratis, H. mediterranea, Reticulofenestra minuta, R. productus,* Sphenolithus heteromorphus and *S. moriformis* Group. This part of the well section is dominated by robust solution resistant species including *Coccolithus pelagicus, Reticulofenestra productus, Cyclicargolithus floridanus* and *Sphenolithus moriformis* Group making up approximately 80% of the total nannofossil assemblage, and suggesting the sediments have suffered the effects of dissolution and/ or reworking. Further evidence of reworking is noted by the occurrence of *Cruciplacolithus tenuis, Ericsonia formosa, Ericsonia robusta, Fasciculithus tympaniformis, Heliolithus kleinpellii, Micula staurophora, P. cretacea, P. grandis, Prinsius bisulcus, Stradneria crenulata, Thoracosphaera operculata, Watznaueria barnesae* and *W. manivitae*, which make up approximately 8% of the total nannofossil assemblage. This part of the well section also contains caved occurrences of *Reticulofenestra pseudoumbilica*. The nannofossil assemblage in this part of the section have not been used to zone the section as it is to poorly preserved. However, this has been dated as Early/ Mid Miocene (NN4/ CN3) based upon the nannofossil assemblage it contains.

The other interval in this section Ch-2/ 45 to Ch-2/ 134 has been sub-divided into 5 zones and 7 subzones:

6.0 Biostratigraphy

1. *Discoaster kuepperi* Zone (IT8): 1(a). *Discoaster kuepperi* Subzone (IT8a).
   1(b). *Sphenolithus conspicuus* Subzone (IT8b).
   1(c). *Tribrachiatus orthostylus* Subzone (IT8c).
2. *Discoaster multiradiatus* Zone (IT9): 2(a). *Discoaster binodosus binodosus* Subzone (IT9a).
   2(b). *Tribrachiatus contortus* A Subzone (IT9b).
   2(c). *Rhomboaster bitrifida* Subzone (IT9c).
3. *Fasciculithus tympaniformis* Zone (IT10): 3(a). *Fasciculithus hayi* Subzone (IT10a).
4. *Heliolithus kleinpellii* Zone (IT11).
5. *Micula murus* Zone (IT13).

1(a). *Discoaster kuepperi* Subzone (IT8a).

The *Discoaster* kuepperi Subzone (IT8a) and occurs between Sample Nos. Ch-2/ 45 and Ch-2/ 58, within the Sinjar Limestone and Aaliji/ Kolosh Clastics Formations. The nannofossil assemblage making up this interval is slightly to moderately overgrown (O-1.5 to O-2), and has a very low abundance rating (maximum number nannofossils per field of view is 0.993). This subzone contains *Braarudosphaera bigelowii, Campylosphaera eodela, Chiasmolithus consuetus, Coccolithus pelagicus, Discoaster deflandrei, D. kuepperi, Discoaster* cf. *D. stella, Ericsonia formosa, Markalius inversus, Micrantholithus flos, Pontosphaera* spp., *Sphenolithus moriformis* Group, *S. radians, Transversopontis pulcher* and *Zygrhablithus bijugatus.* The *Discoaster kuepperi* Subzone (IT8a) contains quite high numbers of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up to 60% of the total nannofossil assemblages. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked specimens including *Arkhangelskiella cymbiformis, Cribrosphaerella ehrenbergii, Cruciplacolithus tenuis, Discoaster mohleri, D. salisburgensis, Eiffellithus gorkae, Ellipsolithus macellus, Ericsonia robusta, Heliolithus kleinpellii, Lithraphidites spp., Micula staurophora, Markalius apertus, Neochiastozygus distentus, N. modestus, Placozygus fibuliformis, P. sigmoides, Prediscosphaera cretacea, P. grandis, Prinsius bisulcus, P. dimorphosus, P. martini, Quadrum gartneri, Q. gothicum, Q. trifidum, Sphenolithus anarrhopus, Stradneria crenulata, Thoracosphaera operculata, Toweius eminens, T. tovae,* *Watznaueria barnesae* and *W. manivitae*, which makes up approximately 40% of the total nannofossil assemblage. The *Discoaster kuepperi* Subzone (IT8a) also contains caved examples of *Cyclicargolithus floridanus* and *Reticulofenestra productus*.

1(b) *Sphenolithus conspicuus* Subzone (IT8b).

This subzone occurs between Sample Nos. Ch-2/ 59 and Ch-2/ 61, within the Aaliji Formation and contains a slightly to moderately overgrown nannofossil assemblage with a very low to low abundance ratings (number of nannofossils per field of view ranges from 0.385 to 1.006). The *Sphenolithus conspicuus* Subzone (IT8b) contains the same taxa as the zone above with the addition of *Discoaster barbadiensis*, *Lophodolithus nacens*, *Micrantholithus pinguis*, *Neococcolithes protenus*, *Sphenolithus conspicuus* and *S. editus*, but without *Ellipsolithus macellus*, *Ericsonia robusta* and *Sphenolithus predistentus*. The *Sphenolithus conspicuus* Subzone (IT8b) contains quite high numbers of *Coccolithus pelagicus*, *Thoracosphaera operculata*, *Sphenolithus* species, and *Discoaster* species making up approximately 46% of the total nannofossil assemblage. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked specimens including *Arkhangelskiella cymbiformis*, *Discoaster salisburgensis*, *Ellipsolithus macellus*, *Ericsonia robusta*, *Heliolithus cantabriae*, *Markalius apertus*, *Micula staurophora*, *Lophodolithus nacens*, *Prediscosphaera cretacea*, *Prinsius bisulcus*, *P. dimorphosus*, *P. martini*, *Quadrum gartneri*, *Scapholithus rhombiformis*, *Stradneria crenulata*, *Thoracosphaera operculata*, *Toweius eminens*, *T. tovae*, *Watznaueria barnesae*, *W. manivitae* and *Zygodiscus bramlettei* making up approximately 40% of the total nannofossil assemblage. This subzone also contains caved *Cyclicargolithus floridanus* and *Reticulofenestra productus* from higher up in the section.

1(c). *Tribrachiatus orthostylus* Subzone (IT8c).

This subzone occurs between Sample Nos. Ch-2/ 62 and Ch-2/ 71 within the Aaliji/ Kolosh Clastics Formations and contains a slightly to moderately overgrown (O-1.5) nannofossil assemblage, and has a very low to low abundance rating (number of nannofossils per field of view ranges from 0.036 to 1.083). The taxa in the *Tribrachiatus orthostylus* Subzone (IT8c) are the same as the *Sphenolithus conspicuus* Subzone (IT8b) with the addition of *Discoaster deflandrei, D. lodoensis, Ellipsolithus macellus*, Reticulofenestra dictyoda, *Sphenolithus elongatus*, S. furcatolithoides, *Tribrachiatus orthostylus* A and *T. orthostylus* B. The *Tribrachiatus orthostylus* Subzone (IT8c) contains relatively high numbers of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up approximately 67% of the total nannofossil assemblage. There are no high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked specimens including *Arkhangelskiella cymbiformis, Cribrosphaerella ehrenbergii, Cruciplacolithus tenuis, Discoaster falcatus, D. multiradiatus, Eiffellithus eximius, E. gorkae, E. turriseiffelii, Ericsonia robusta, Heliolithus cantabriae, Markalius apertus, Microrhabdulus undosus, Micula concava, Micula murus, M. staurophora, Neochiastozygus distentus, N. junctus, Placozygus sigmoides, Prediscosphaera cretacea, P. grandis, Prinsius bisulcus, P. dimorphosus, P. martini, Quadrum gartneri, Q. sissinghii, Sphenolithus anarrhopus, Stradneria crenulata, Thoracosphaera operculata, Toweius eminens, T. tovae, Tranolithus minimus, Watznaueria barnesae* and *W. manivitae*, which make up a maximum of 52% of the total nannofossil assemblage. This subzone also contains caved examples of *Reticulofenestra productus*.

2(a). *Discoaster binodosus binodosus* Subzone (IT9a).

This subzone occurs between Sample Nos. Ch-2/ 72 and Ch-2/ 87, within the Aaliji/ Kolosh Clastics Formation. The nannofossil assemblage in this subzone are slightly to moderately overgrown (O-1.5), and have a very low to low abundance rating (number of nannofossils per field of view ranges between 0.058 to 4.708). The nannofossil assemblage within the *Discoaster binodosus binodosus* Subzone includes *Braarudosphaera bigelowii, Campylosphaera eodela, Chiasmolithus bidens, C. consuetus, Coccolithus pelagicus, Discoaster cf. D. stella. D. barbadiensis, D. binodosus binodosus, D. falcatus, D. lodoensis, D. multiradiatus, D. salisburgensis, Ellipsolithus macellus, Ericsonia robusta, Lophodolithus nacens, Markalius inversus,* *Micrantholithus flos, M. pinguis, Neococcolithes protenus, Neochiastozygus distentus, Pontosphaera* spp., *Rhabdolithus solus, Sphenolithus conspicuus, S. editus, S. moriformis* Group, *S. radians, Toweius eminens, T. pertusus, Transversopontis pulcher, Tribrachiatus orthostylus* A, *T. orthostylus* B, ana *Zygrhablithus bijugatus.* The *Discoaster binodosus binodosus* Subzone (IT9a) contains relatively high numbers of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up approximately 46% of the total nannofossil assemblage. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked species including *Arkhangelskiella cymbiformis, Chiastozygus litterarius, Cribrosphaerella ehrenbergii, Cruciplacolithus latipons, C. tenuis, Discoaster mahmoudii, Eiffellithus eximius, E. gorkae, Ellipsolithus distichus, Heliolithus cantabriae, Markalius apertus, Micula concava, M. staurophora, Placozygus sigmoides, Prediscosphaera cretacea, P. grandis, Prinsius bisulcus, P. martini, Quadrum gartneri, Q. gothicum, Q. sissinghii, Q. trifidum, Stradneria crenulata, Toweius tovae, Tranolithus minimus, Watznaueria barnesae, W. manivitae* and *Zygodiscus bramlettei*, which makes up approximately 25% of the total nannofossil assemblage. This subzone also contains *Reticulofenestra productus, Discoaster kuepperi, Ericsonia formosa* and *Neococcolithes dubius*, caved from higher up in the section.

2(b). *Tribrachiatus contortus* A Subzone (IT9b).

This subzone occurs between Sample Nos. Ch-2/ 88 and Ch-2/ 93, within the Aaliji/ Kolosh Clastics Formation. The nannofossil assemblage in this subzone are slightly to moderately overgrown (O-1.5), and have a low abundance rating (maximum number of nannofossils per field of view 2.853). The nannofossil assemblage within this subzone is the same as the Discoaster binodosus binodosus Zone (IT9a) with the addition of *Neochiastozygus chiastus, Rhabdolithus solus* and *Tribrachiatus contortus* A but, excluding *Tribrachiatus orthostylus* B. The *Tribrachiatus contortus* A Subzone (IT9a) contains quite high amounts of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up approximately 30% of the total nannofossil assemblage. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked specimens including *Chiastozygus litterarius, Cribrosphaerella ehrenbergii, Cruciplacolithus latipons, C. tenuis, Eiffellithus eximius, E. gorkae, E. turriseiffelii, Heliolithus cantabriae, Markalius apertus, Micula staurophora, Prediscosphaera cretacea, P. grandis, Prinsius bisulcus, P. dimorphosus, P. martini, Stradneria crenulata, Toweius tovae, Watznaueria barnesae, W. manivitae* and *Zygodiscus bramlettei*, which makes up approximately 14% of the total nannofossil assemblage. This subzone also contains caved examples of *Ericsonia formosa, Micrantholithus flos, M. pinguis, Sphenolithus editus, S. radians, Tribrachiatus orthostylus A* and *Zygrhablithus bijugatus*.

2(c). ***Rhomboaster bitrifida*** **Subzone (IT9c).**

This subzone occurs between Sample Nos. Ch-2/ 93 and Ch-2/ 107, which forms part of the Aaliji/ Kolosh Clastics Formations, and the nannofossil assemblages are typically slightly to moderately overgrown (O-1 to O-1.5), and have a low abundance rating (maximum number of nannofossils per field of view 7.116). The nannofossil assemblage is the same as Tribrachiatus contortus A Subzone (IT9b) with the addition of *Rhomboaster bitrifida* but excluding *Neochiastozygus chiastus, Tribrachiatus orthostylus* A and *T. orthostylus* B. The *Rhomboaster bitrifida* Subzone (IT9a) contains quite high amounts of *Coccolithus pelagicus, Thoracosphaera operculata, Sphenolithus* species, and *Discoaster* species making up approximately 33% of the total nannofossil assemblage. There are no real high percentages of robust, solution resistant species but there is evidence of reworking as the subzone also contains several reworked specimens including *Chiastozygus litterarius, Cribrosphaerella ehrenbergii, Cruciplacolithus latipons, C. tenuis, Discoaster mohleri, Eiffellithus gorkae, Fasciculithus involutus, F. thomasii, F. tympaniformis, Markalius apertus, Micula staurophora, Prediscosphaera cretacea, P. grandis, Prinsius bisulcus, P. dimorphosus, P. martini, Quadrum gartneri, Q. gothicum, Stradneria crenulata, Toweius tovae, Tranolithus minimus, Watznaueria barnesae, W. manivitae* and *Zygodiscus bramlettei*, which makes up approximately 16% of the total nannofossil assemblage. This subzone also contains caved taxa including *Discoaster kuepperi*, *Discoaster* cf. *D. stella*, *Ericsonia formosa*, *Micrantholithus flos*, *M. pinguis*, *Neococcolithes dubius*, *Rhabdolithus truncata*, *Sphenolithus conspicuus*, *S. radians*, *Transversopontis pulcher*, *Tribrachiatus orthostylus* B and *Zygrhablithus bijugatus*.

3. *Fasciculithus tympaniformis* Zone (IT10).

This zone occurs between Sample Nos. Ch-2/ 108 and Ch-2/ 125, which is in the Aaliji/ Kolosh Clastics Formations, and is split up in this section using the acme occurrence of *Fasciculithus hayi* as in the Kirkuk No. 116 well section.

3(a). The *Fasciculithus hayi* Subzone (IT10a).

This subzone occurs between Sample No. Ch-2/ 109 to sample Ch-2/ 115, and the nannofossil assemblage is very slight to moderately overgrown (O-0.5 to O-1.5), and has a low to moderate abundance rating (number of nannofossils per field of view 1.517 to 16.778). The *Fasciculithus hayi* Subzone (IT10) again contains a considerable variety of *Fasciculithus* species, which make up a significant amount of the total nannofossil assemblage. The nannofossil assemblage contains *Braarudosphaera bigelowii*, *Coccolithus pelagicus*, *Cruciplacolithus tenuis*, *D. binodosus binodosus*, *D. mohleri*, *D. multiradiatus*, *D. salisburgensis*, *Ellipsolithus distichus*, *E. macellus*, *Ericsonia robusta*, *Fasciculithus* sp. 1, *F. alanii*, *F. bobii*, *F. hayi*, *F. thomasii*, *F. involutus*, *F. tympaniformis*, *Markalius inversus*, *Neochiastozygus distentus*, *N. junctus*, *N. protenus*, *Placozygus sigmoides*, *Pontosphaera* spp., *Prinsius bisulcus*, *P. martini*, *Rhomboaster bitrifida*, *Scapholithus rhombiformis*, *Sphenolithus anarrhopus*, *S. moriformis Group*, *Thoracosphaera operculata*, *Toweius eminens*, *T. pertusus*, *T. tovae* and *Zygodiscus bramlettei*. This part of the well section is dominated by *Coccolithus pelagicus*, *Ericsonia robusta*, *Fasciculithus* spp., *Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up to 80% of the total nannofossil assemblage. The *Fasciculithus hayi* Subzone (IT10a) also contains reworked Cretaceous and Mid Palaeocene taxa include *Arkhangelskiella cymbiformis*, *Campylosphaera eodela*, *Cribrosphaerella ehrenbergii*, *Eiffellithus turriseiffelii*, *Lophodolithus nacens*, *Markalius apertus*, *Micula concava*, *M. staurophora*, *Prediscosphaera cretacea*, *P. grandis*, *Prinsius dimorphosus*, *Quadrum* *gartneri, Q. gothicum, Stradneria crenulata, Tranolithus minimus, Watznaueria barnesae* and *W. manivitae, which makes up approximately 10% of the total nannofossil assemblage.* The *Fasciculithus hayi* Subzone (IT10a) also contains caved examples ~~of *Discoaster kuepperi*~~, *Micrantholithus flos, Micrantholithus pinguis, Sphenolithus editus, S. radians, Tribrachiatus orthostylus* B and *Zygrhablithus bijugatus.*

The Fasciculithus tympaniformis Zone (IT10) itself contains the same taxa, with the exclusion of *Fasciculithus* sp. 1, *Fasciculithus bobii* and *Fasciculithus richardii*, and the caved *Micrantholithus flos, Micrantholithus pinguis* and *Sphenolithus editus*, plus the reworked *Quadrum gartneri* and *Quadrum gothicum*. This zone also contains in addition to the *Fasciculithus hayi* subzone *Discoaster diastypus*, caved *Discoaster kuepperi, D. lodoensis* and *Transversopontis pulcher*, and reworked *Fasciculithus bitectus, F. janii, Neochiastozygus denticulatus* and *N. perfectus*. This zone is again dominated by *Coccolithus pelagicus, Ericsonia robusta, Fasciculithus* spp., *Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up to 78% of the total nannofossil assemblage. The *Fasciculithus tympaniformis* Zone (IT10) contains reworked Cretaceous and Mid Palaeocene which makes up a maximum of 17% of the total nannofossil assemblage at the boundary between the *Discoaster multiradiatus Zone* (IT9) and the *Fasciculithus tympaniformis* Zone (IT10) perhaps indicating an unconformable relationship.

4. *Heliolithus kleinpellii* Zone (IT11).

This zone occurs between Sample Nos. Ch-2/ 126 and Ch-2/ 131, towards the base of the Aaliji/ Kolosh Clastics Formations. The top of this zone is defined by the FDO of *Heliolithus kleinpellii*, and the base in this section is defined by the FDO of *Micula murus*. The nannofossil assemblages within this zone is mainly slightly overgrown (O-1) and has a low to moderate abundance rating (number of nannofossils per field of view ranges from 1.892 to 13.043). The *Heliolithus kleinpellii* Zone (IT11) is thin compared to the age range it represents (from NP6/ CP5 to lowermost NP9/ CP8a). This makes identifying the caved and reworked parts of ranges of some taxa difficult.

The nannofossil assemblage within the *Heliolithus kleinpellii* Zone (IT11) includes *Braarudosphaera bigelowii, Chiasmolithus consuetus, Campylosphaera eodela, Coccolithus pelagicus, Cruciplacolithus tenuis, Discoaster multiradiatus, Ellipsolithus macellus, Ericsonia robusta, Fasciculithus alanii, F. hayi, F. involutus, F. thomasii, F. schaubii, F. tympaniformis, Heliolithus kleinpellii, Neochiastozygus denticulata, N. distentus, N. junctus, N. perfectus, Neococcolithes protenus, Placozygus sigmoides, Prinsius bisulcus, P. dimorphosus, P. martini, Rhomboaster bitrifida, Scapholithus rhombiformis, Sphenolithus anarrhopus, S. moriformis Group, Thoracosphaera operculata, Toweius eminens, T. pertusus* and *Toweius tovae*. The zone is dominated by *Coccolithus pelagicus, Fasciculithus tympaniformis, Prinsius* spp., *Sphenolithus* spp., *Thoracosphaera operculata* and *Toweius* spp., making up approximately 95% of the total nannofossil assemblage. The *Heliolithus kleinpellii* Zone (IT11) also contains reworked Cretaceous and Mid Palaeocene taxa including plus some from a possible *Fasciculithus pileatus* Zone (IT12) which has been totally reworked into the zone above. The taxa recorded includes *Cribrosphaerella ehrenbergii, Fasciculithus bitectus, F. ulii, Microrhabdulus undosus, Micula staurophora, Neochiastozygus modestus, Prediscosphaera cretacea, P. grandis, Quadrum gartneri, Q. gothicum, Stradneria crenulata, Watznaueria barnesae* and *W. manivitae*, which makes up maximum of 5% of the total nannofossil assemblage close to the boundary between the Late Cretaceous and the Mid Palaeocene. The zone also contains caved taxa which include *Ericsonia formosa, Micrantholithus flos, Sphenolithus radians* and *Zygrhablithus bijugatus*.

5. *Micula murus* Zone (IT13).

This zone occurs between Sample Nos. Ch-2/ 132 and Ch-2/ 133 within the Tanjero Clastics Formation. The nannofossil assemblage is slightly to moderately overgrown (O-1.5) and has a low abundance rating (maximum number of nannofossils per field of view 6.0). The *Micula murus* Zone (IT13) contains *Arkhangelskiella cymbiformis, Ceratolithoides kamptneri, Cribrosphaerella ehrenbergii, Eiffellithus turriseiffelii. Lithraphidites spp., Markalius inversus, Micula concava, M. murus, M. staurophora, Placozygus sigmoides, Prediscosphaera cretacea, P. grandis, Stradneria crenulata,* *Thoracosphaera operculata, Watznaueria barnesae* and *W. manivitae*. This zone also contains reworked taxa from the Early Maastrichtian and the Late Campanian: *Eiffellithus eximius, Quadrum gartneri* and *Tranolithus minimus*. The *Micula murus* Zone (IT13) also contains caved taxa including *Cruciplacolithus tenuis, Discoaster multiradiatus, Ellipsolithus macellus, Ericsonia formosa, E. robusta, Fasciculithus hayi, F. tympaniformis, Neochiastozygus denticulatus, N. distentus, N. perfectus, Prinsius dimorphosus, P. martini, Scapholithus rhombiformis, Sphenolithus moriformis* Group, *T. eminens, Toweius tovae, Zygodiscus bramlettei* and *Zygrhablithus bijugatus*.

Summary:

A summary diagram showing the location and the main points of information gathered from Chemchemal No. 2 during this study can be seen Figure 6.11. The main points of information gathered from this well section are:

- 133 cuttings samples taken from the Lower Fars (Transition Beds), Pila Spi Limestone, Gercus Red Beds, Khurmala Limestone, Sinjar Limestone, Aaliji/ Kolosh Clastics and the Shiranish Formations.
- Overall the Chemchemal No. 2 well section is moderately well preserved and 6 zones and 2 Subzones can be defined in this well section:

  1. *Discoaster kuepperi* Zone (IT8). Between Sample Nos. Ch-2/ 45 and Ch-2/ 71 from the lower part of the Sinjar Limestone and Aaliji/ Kolosh Formations:

  Discoaster kuepperi Subzone (IT8a). Between Sample Nos. Ch-2/ 45 and Ch-2/ 58.

  Sphenolithus conspicuus Subzone (IT8b). Between Sample Nos. Ch-2/ 59 and Ch-2/ 61.

  Tribrachiatus orthostylus Subzone (IT8c). Between Sample Nos. Ch-2/ 62 and Ch-2/ 71.

  2. *Discoaster multiradiatus* Zone (IT9). Between Sample Nos. Ch-2/ 72 and Ch-2/ 107 from the Aaliji/ Kolosh Clastics Formations:

  Discoaster binodosus binodosus Subzone (IT9a). Between Sample Nos. Ch-2/ 72 and Ch-2/ 86.

  Tribrachiatus contortus A Subzone (IT9b). Between Sample Nos. Ch-2/ 87 and Ch-2/ 92.

  Rhomboaster bitrifida Subzone (IT9c). Between Sample Nos. Ch-2/ 93 and Ch-2/ 107.

  3. *Fasciculithus tympaniformis* Zone (IT10). Between Sample Nos. Ch-2/ 108 and Ch-2/ 125 from the Aaliji/ Kolosh Clastics Formations:

  Fasciculithus hayi Zone (IT10a). Between Sample Nos. Ch-2/ 109 and Ch-2/ 115.

  4. *Heliolithus kleinpellii* Zone (IT11). Between Sample Nos. Ch-2/ 126 and Ch-2/ 131 from the Aaliji/ Kolosh Clastics Formations.

  5. *Micula murus* Zone (IT13). Between Sample Nos. Ch-2/ 132 and Ch-2/ 133 from the Tanjero Clastics Formation.

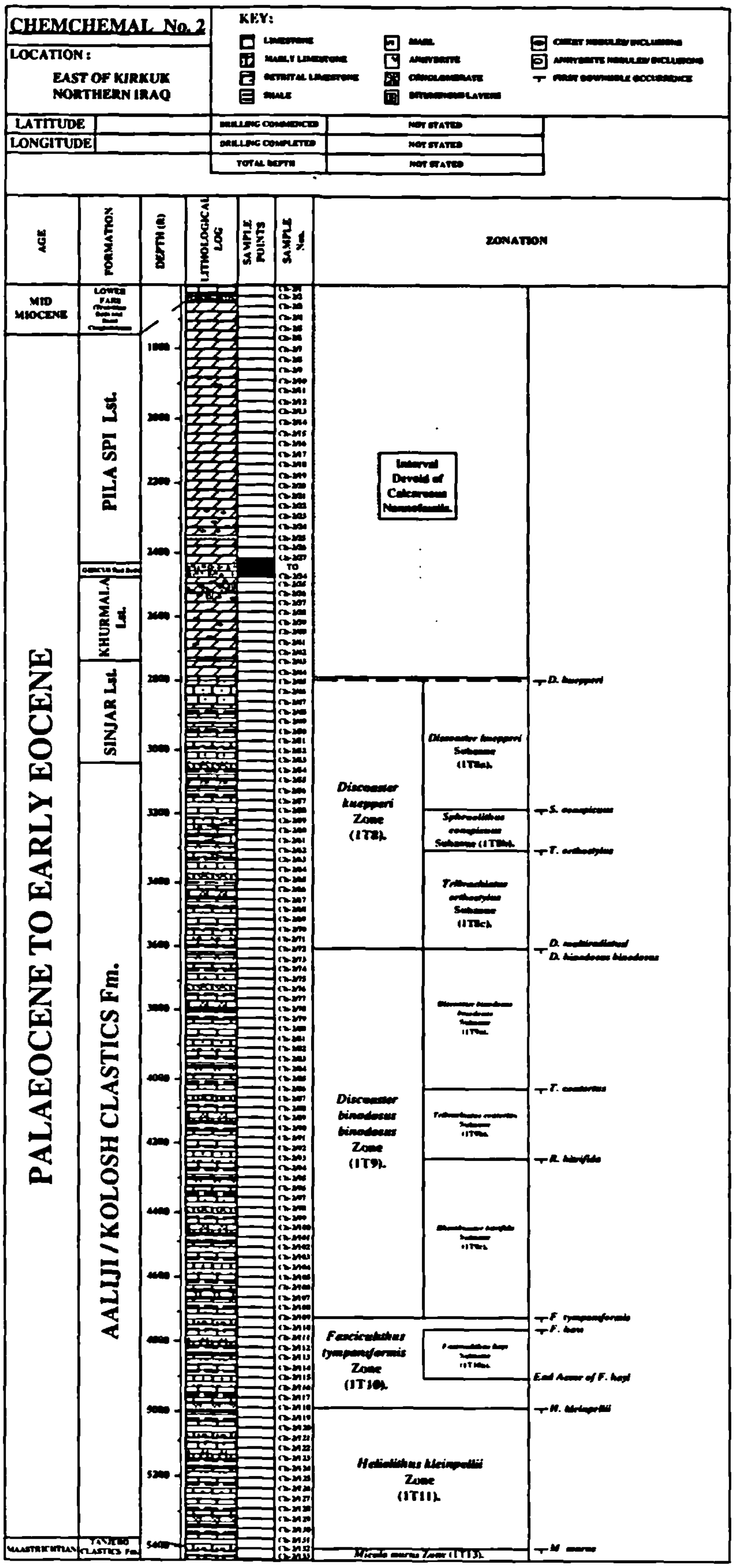


Figure 6.11 Summary Diagram of the Main Bistratigraphic Information from I.P.C. Well Chemchemal No. 2.

- High percentages of reworked taxa were noted at the *Discoaster multiradiatus* Zone (IT9)/ *Fasciculithus tympaniformis* Zone (IT10) boundary, and the Late Cretaceous/ Mid Palaeocene boundary.

6.4 Biostratigraphic Correlations.

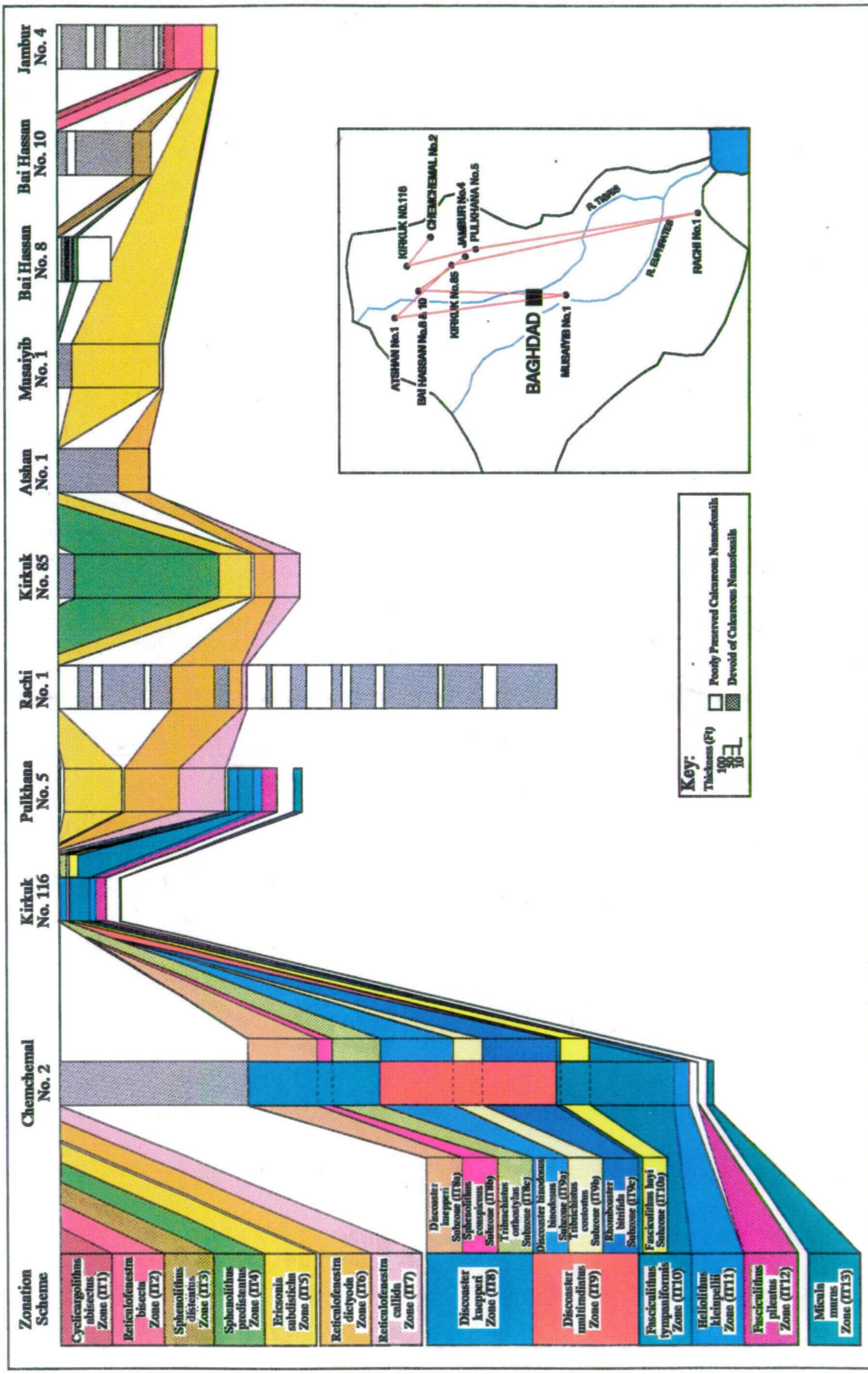
The regional correlation of the zones and subzones established during this study is shown in Figure 6.12. In addition the calcareous nannofossil zonation scheme developed during this study, has been correlated with both global and regional calcareous nannofossil and planktonic foraminiferal zonation schemes, and the magnetobiochronologic timescale.

6.4.1 Calcareous Nannofossil Zonation Schemes:

The calcareous nannofossil zonation scheme developed during this present study has been correlated to the two most widely used global Tertiary zonation schemes, those of Martini (1971) and Okada and Bukry (1980). This exercise was carried out so that Iraq could be put into a global time framework (see Figure 6.13). In addition other calcareous nannofossil zonation schemes established in various Middle Eastern countries, as well as surrounding off-shore areas of the Middle East have also been correlated to the zonation scheme proposed in this present study. This correlation has enabled Iraq to be fitted into a regional stratigraphic framework (see Figure 6.15 and 6.16a-c). These zonation schemes are discussed in detail below, firstly with the global zonation schemes and then with the regional zonation schemes.

6.4.1(i) Global Calcareous Nannofossil Zonation Schemes.

Martini (1971) proposed a global calcareous nannofossil zonation scheme comprises 25 zones for the Palaeogene (coded NP1 to NP25) and 21 zones for the Neogene and Quanternary (coded NN1 to NN21). His scheme is based upon a review of previous work, supplemented by the study of samples from both onshore and offshore sections from various parts of the world including; Denmark, Germany, Tunisia, Austria, New Zealand, Sweden, Australia, France, the Atlantic Ocean, Mexico, Oman, Spain, the Pacific Ocean, United States of America, Belgium, England, Cuba, the Indian Ocean,



6.12 Correlation of the Calcareous Nannofossil Zones over the Ten Well Sections Analysed During this Present Study.

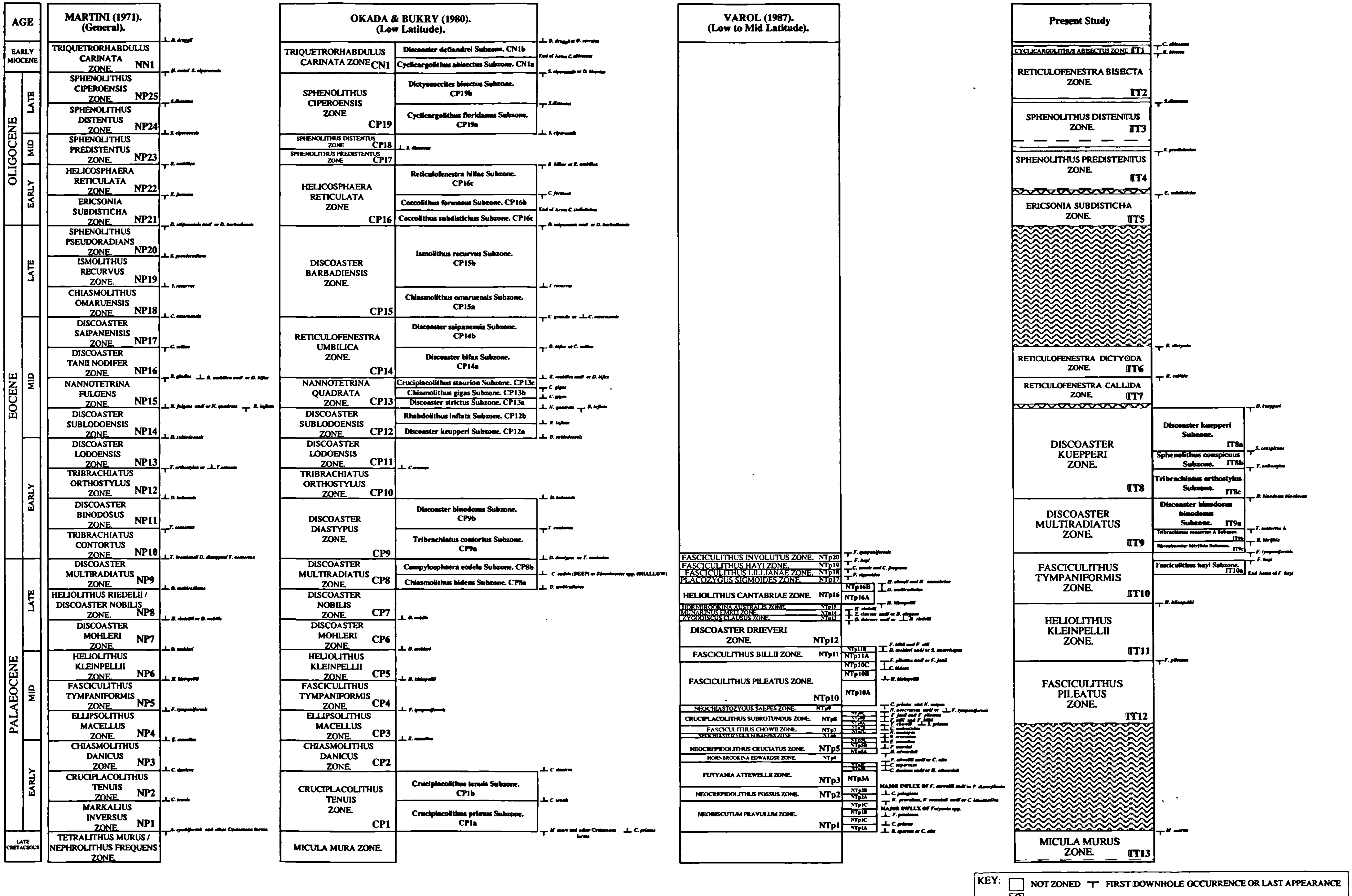


Figure 6.13 Correlation between Global Calcareous Nannofossil Zonation Schemes and the Calcareous Nannofossil Zonation Scheme Developed During This Present Study.

Czechoslovakia, Commonwealth of Independent States (Crimea, Mandrikovka, Nal'Chik and Tscherkessk), Hungary, Barbados, Syria, Gabon, Malta, Trinidad, Romania, Haiti, Indonesia, Fidji Islands and the Mediterranean Sea. The zones that Martini established are based upon first and last occurrences of certain marker species. These marker species are shown in Figure 6.13.

Okada and Bukry (1980) proposed calcareous nannofossil zonation scheme for use principally in low latitude regions. This zonation scheme was modified from previous work by Bukry (1973a, 1975) on Deep Sea Drilling Project (DSDP) sites from Leg 15 (Caribbean Sea) and Leg 32 (Northwestern Pacific Ocean). In all 19 zones and 20 subzones were defined from the Palaeogene (coded CP1 to CP19, subzones having been given the suffix a, b, or c) and 15 zones and 24 subzones from the Neogene and Quaternary (coded CN1 to CN15, subzones having been given the suffix a, b, or c). The zones established by Okada & Bukry (1980) that equate to the time period studied in Iraq, are for the main part based upon first and last occurrences of certain marker species. However, occasionally they used the beginning and end of acmes of certain marker taxa to establish their zonation scheme. An example of this latter type of zone is the *Coccolithus subdistichus* Zone; the base of which is marked by the last occurrence of *Discoaster barbadiensis* or *Discoaster saipanensis* and the top is marked by the end of an acme of *Coccolithus subdistichus*. The nominate taxa of the Okada and Bukry (1980) scheme can be seen in Figure 6.13.

Gartner (1977), presented an overview of the problems in using zonation schemes from the Mesozoic and the Cenozoic. In his review Gartner studied the zonation schemes of Martini (1971) and of Bukry (1971, 1975) which formed the main basis for the later Okada & Bukry (1980) zonation scheme. Gartner pointed out that Martini based his studies mainly on outcrop material which had a pronounced hemipelagic aspect. Consequently the zonation scheme established from these samples is made up of a combination of cosmopolitan and provincial calcareous nannofossil forms, some of which were notoriously unreliable according to Gartner. Gartner (1977), also pointed out that the numbering system used by Martini for his zones is difficult to update. In his study of the Bukry (1971, 1975) zonation schemes Gartner noted that Bukry based his work on samples from DSDP well sites and as a result he used more open marine cosmopolitan forms. However, he also noted that Bukry used provincial forms when suitable cosmopolitan species were lacking.

Varol (1989) established a detailed zonation scheme for the Palaeocene for low to mid latitudes. He studied drill cuttings, field samples sidewall cores and conventional core samples from the Solomon Islands, New Zealand, Australia, Papua New Guinea, Indonesia (mainly Irian Jaya), the Phillippines, Malaysia, Brunei, Burma, Sri Lanka, India, East Africa (including Sudan), Middle East countries, Libya, Tunisia, Turkey (detailed study of the Kokaksu Section, Zonguldak, northern Turkey), West Africa, Northwest Europe and the Caribbean area. He established 20 zones based upon last occurrences (LO's) and acmes of species, and established 24 subzones based upon first occurrences (FO's) and acmes of species. He coded the zones NTp1 to NTp20, and the subzones he labeled with the suffix's A, B, C, or D.

The zonation scheme of Martini (1971) proved to be of most use in the study area probably for two reasons:

(1). The markers species Martini selected are derived from outcrop samples which had a marked hemipelagic aspect, as pointed out by Gartner (1977). It is envisaged that the current study area had a similar hemipelagic aspect during the time period studied as Iraq formed part of a basin between the colliding Afro-Arabian and Eurasian continental plates.

(2). When Martini established his zonation scheme he used some outcrop samples from Syria and the Mediterranean Sea which lie in the general vicinity of Iraq.

The calcareous nannofossil zonation scheme established by Okada and Bukry (1980) is of less use in the study area as it is founded upon DSDP core samples which have a more open marine aspect than the outcrop samples used by Martini (1971). As a result the Okada and Bukry (1980) scheme uses mainly cosmopolitan forms as zonal markers instead of the more provincial forms used by Martini (1971). In addition the

Okada and Bukry (1980) scheme is intended for use mainly in low latitudes.

The zonation scheme proposed by Varol (1989) was developed for the Palaeocene for use in mid to low latitudes. His scheme is useful in this current study as he uses the last occurrences of many taxa to define his zonation scheme and in addition, Varol studied samples from Middle Eastern countries including Turkey and Libya when he was establishing his scheme.

6.4.1(ii) Regional Calcareous Nannofossil Zonation Schemes.

The locations of the outcrop sections and DSDP sites studied by various authors to produce calcareous nannofossil zonation schemes for the Middle East region can be seen in Figure 6.14. These zonation schemes have been correlated to the calcareous nannofossil zonation scheme presented in this study thus enabling to be placed into a regional stratigraphic framework (see Figures 6.15, 6.16a-c). Haq and Aubry (1981) established zonation schemes for many countries in North Africa and the Middle East, during their biostratigraphic and palaeobiogeographic studies in this region. However, the number of samples studied in each section is generally low and therefore the accurate definition of zones is unlikely. The Middle Eastern onshore and offshore sections considered during this study by other authors are listed below by country, with some details of the zonation schemes they have established.

Offshore Well Sections:

Bukry (1973e) proposed a zonation scheme for the DSDP Leg 24 based upon 305 conventional core samples were taken from 337 cores, from 8 drill sites in the Indian Ocean and the Gulf of Aden. However, only the Indian Ocean sites yielded sediments of an equivalent age to those studied in Iraq. He proposed 18 zones and 14 subzones for the Palaeocene to Early Miocene in this area.

Roth (1973b) restudied the 8 well sites from the DSDP Leg 24, and proposed a slightly different zonation scheme to that of Bukry (1973b). He recognised 23 zones but no subzones for the Late Cretaceous to Early Miocene sequence.

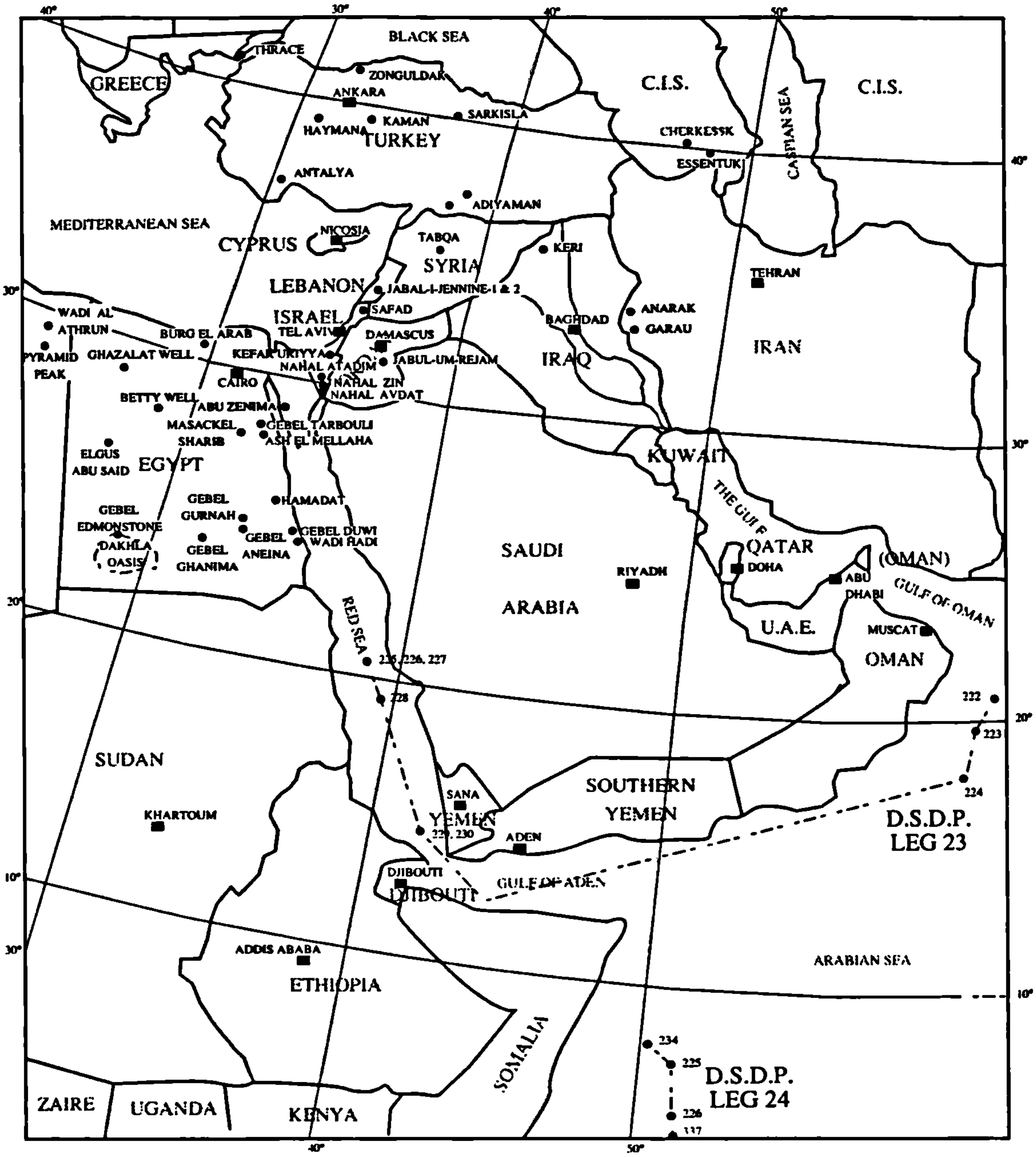


Figure 6.14 Location Map of Published Calcareous Nannofossil Zonation Schemes from Outcrop and D.S.D.P. Sections in the Middle East Region.

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Bukry (1974) produced a zonation scheme for the DSDP Leg 23 based on 289 conventional core samples taken 311 cores from 12 well sites from the Arabian and Red Seas. However, only the Arabian Sea wells (Sites 219 to 224) yielded sediments of a equivalent age to that studied during this project. He proposed 16 zones and 10 subzones for the Late Paleocene to the Early Miocene, not all of which are well defined.

Boudreaux (1974) restudied the well sites of the DSDP Leg 23 and proposed a less complete zonation scheme than Bukry (1974) for the equivalent time period studied in Iraq. The zonation scheme he proposed comprises 11 zones from the Early Eocene to Early Miocene, not all of which are well defined.

These offshore zonation schemes have be correlated to the calcareous nannofossil zonation scheme proposed during this study and can be seen in Figure 6.15.

Commonwealth of Independent States (C.I.S):

Haq and Aubry (1981) studied two outcrop sections at Essentuki and Cherkessk in the Caucasus Mountains, in the C.I.S. They established 3 zones in Essentuki outcrop section on the Podkoom River based upon 6 outcrop samples taken from the Elburgan Formation. They also established 3 zones in the Cherkessk outcrop section on Kuban River based upon 5 outcrop samples again taken from the Elburgan Formation. Haq and Aubry (1981) assigned both sections to the Palaeocene.

Egypt:

Kerdany (1970) proposed a zonation scheme for Egypt based upon seven outcrop sections: El Gus Abu Said, Gebel Edmonstone (Dakhla Oasis), Gebel Ghanima, Gebel Aweina, Gebel Gurnah, Gebel Abu Had and Masak El Sharib. He established 6 zones which were assigned to the Palaeocene to Early Eocene.

Shafik and Stradner (1971) proposed a zonation scheme for Egypt based upon six outcrop sections: Gebel Tarbouli, Gebel Duwi, Ash El-Mellaha, Hamadat, Wadi Had

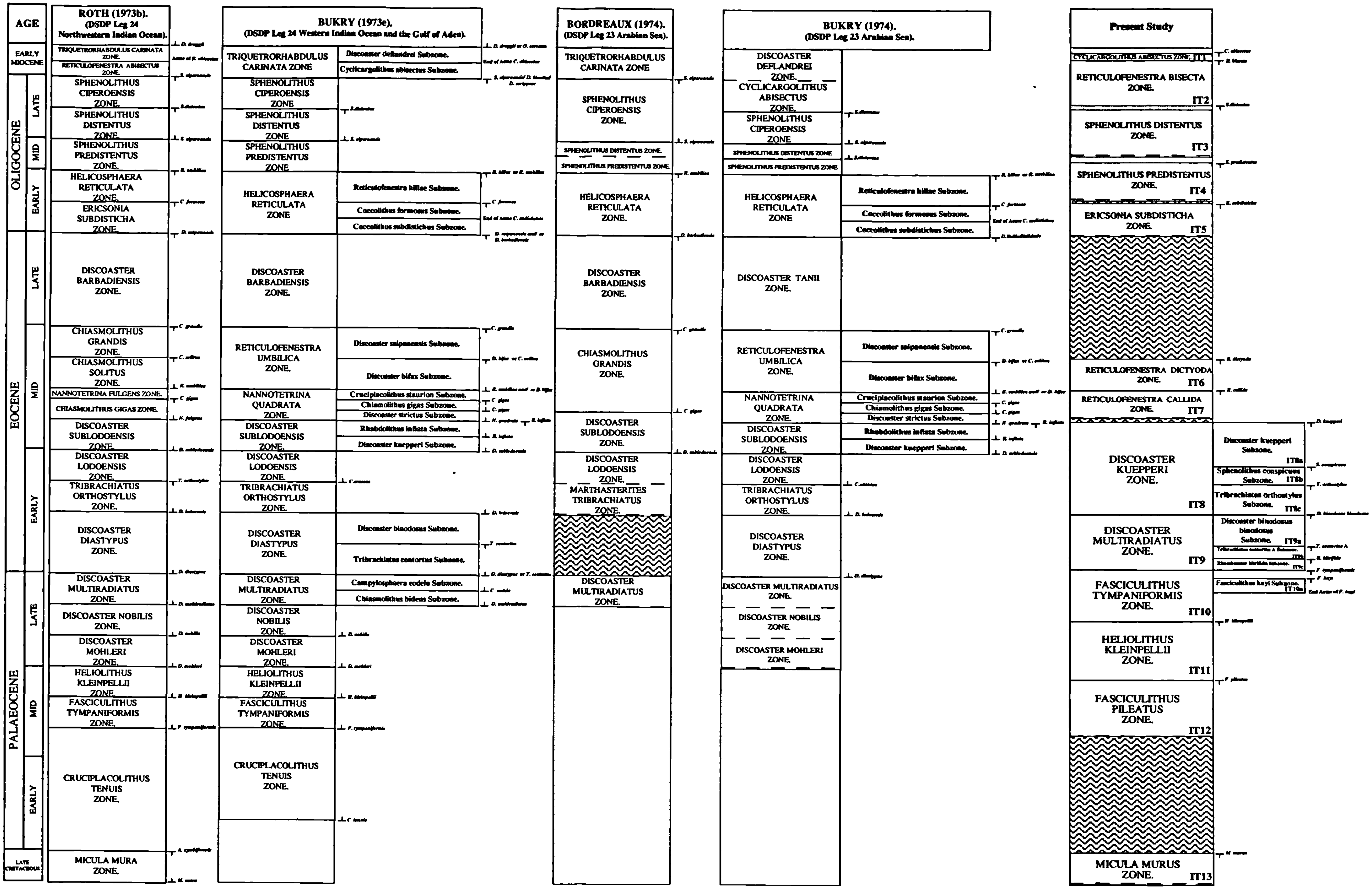

Figure 6.15 Correlation between Offshore Arabian Calcareous Nannofossil Zonation Schemes and the Calcareous Nannofossil Zonation Scheme Developed during this Present Study.

KEY: NOT ZONED — FIRST DOWNHOLE OCCURRENCE OR LAST APPEARANCE
HIATUS — FIRST APPEARANCE

and Haraween. They studied the Thebes Limestone, Esna Shale, Dakhla Shale and Tarawan Chalk units, and proposed 5 zones which they assigned to Late Palaeocene to Early Eocene.

Sadek (1972) proposed a zonation scheme for Egypt based on outcrop and well material from the Gebel Mokattam, Burg El Arab Well, Betty Well and Gazalat Well (Northwestern Desert). Sadek (1972) also based his zonation scheme on early work on outcrop samples from Um El Huetat, on the Red Sea Coast by Sadek and El Razik (1970). Sadek (1972) proposed 5 zones which he assigned to the Palaeocene to Mid Eocene.

El-Dawoody and Bakarat (1973) produced a zonation scheme based upon outcrop samples from the Duwi section, in the Ouseir District in the Western Desert of Egypt. They sampled the Upper Dakhla Shale, Esna Shale, Thebes Shale and the Thebes Limestone Formations, and proposed 3 zones which they assigned to the Early Palaeocene to Early Eocene.

Perch-Nielsen *et al.* (1974) proposed a zonation scheme for the Gebel Aweina and Gebel Gurnah sections in the Nile valley, Egypt. In all 30 outcrop samples were collected from the Sharawna Shale Formation (comprising Lower Sharawna Shale, Middle Sharawna Marl and the Upper Sharawna Shale Members), Owaina Shale Formation (comprises Lower Owaina Shale and the Kilabiya Chalk Members) and the Luxor Formations (comprises Gurnah Calcareous Shale and the Thebes Limestone Members). From these 30 outcrop samples 10 zones were established for the Maastrichtian to Early Eocene, not all of which are well defined.

Abdelmalik *et al.* (1974) produced a zonation scheme for an outcrop section at Abu Zenima, West Central Sinai, Egypt. They collected 37 outcrop samples from the Sudr Chalk, Dakhla Shale, Tarawan Chalk, Esna Shale and the Thebes Limestones Formations, and established 6 zones ranging in age from the Mid Maastrichtian to Early Eocene.

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El-Dawoody and Zidan (1976) studied the Dakhla Oasis outcrop section in the Western Desert of Egypt. They sampled the Lower Owaina Shale and the Tarawan Chalk Formations and proposed seven zones for this outcrop section which they assigned to the Palaeocene.

Iran:

Haq (1971a) established a zonation scheme for the Palaeocene based upon two outcrop sections in northeastern Iran, the Tange-Bijar section in the Galal Anarak area and the Kabir Kuh section in Garau Valley area. He established 6 zones and 2 subzones in the Tange-Bijar section based upon 16 samples. Haq (1971a) also established 2 zones and 2 subzones for the Kabir Kuh outcrop section based upon 14 samples, and assigned both sections to the Palaeocene.

Iraq:

El-Dawoody and Elewi (1984) proposed the only previous calcareous nannofossil zonation scheme for Iraq. This zonation scheme is based upon 90 samples taken from a 212 metre thick outcrop section of the Jaddala Formation on the northern limb of the Sinjar anticline, near Kersi village (36°23'18"N, 41°43'24"E). In all they proposed 6 zones for the outcrop section based upon first and last occurrences of marker species which they assigned to the Eocene. El-Dawoody and Elewi, recognised Late Eocene nannofossil assemblages in the Jaddala Formation. These were not recognised during this study, despite the Jaddala Formation being analysed in 4 separate well sections in Iraq. More details on the zonation scheme can be seen in Figure 6.16 and the zonation is further discussed under 2.1.5 Jaddala Formation in the General Geology chapter 2.0.

Israel:

Moshkovitz (1967) studied 4 outcrop sections: one near Safad in northern Israel close to the Lebanese border, one near Kefar Urivya in central Israel, and two in southern Israel one on the Nahal Atadim and one on the Nahal Zin. Based upon these outcrop sections he proposed 1 zone and two subzones, which were assigned to the Late

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Palaeocene.

Romein (1979) proposed a zonation scheme for the Nahal Avdat Section, Northern Negev, Israel ~~based upon~~ 101 ~~outcrop samples~~, as part of his investigations into calcareous nannofossil lineages from the Early Palaeogene. He established 15 zones within the Late Maastrichtian to Early Eocene sequence of the outcrop section.

Jordan:

Haq and Aubry (1981) studied the Jabal-um-Rejam outcrop section south of Ammam, and established 6 zones based upon 13 outcrop samples taken from the Palaeocene to Early Eocene succession.

Lebanon:

Haq and Aubry (1981) studied the Jabal-i-Jennine No. 1 outcrop section and established only 1 zone based upon 6 outcrop samples. They assigned the zone to the Early Eocene. They also studied the Jabal-i-Jennine No. 2 outcrop section and established 4 zones which they assigned to the Early Eocene however, not all the zones are clearly defined.

Libya:

Haq and Aubry (1981) studied two outcrop sections in northeastern Libya. They established 6 zones in the Wādī al Athrūn outcrop section, in northern Cyrenaica based upon 11 outcrop samples taken from the Apollonia Limestone Formation. They assigned an Early to Mid Eocene age to this formation. Haq and Aubry (1981) established 6 zones in the Pyramid Peak outcrop section, in northern Cyrenaica based upon 67 samples again taken from the Apollonia Limestone Formation. They assigned the zones to the Early to Mid Eocene, but the zones are mixed and not as clearly defined as the zones in the Wādī al Athrūn outcrop section.

Syria:

Haq (1971b) established a zonation scheme for the Oligocene of Syria based upon 16 samples taken from a borehole at a dam site at Tabqa. This zonation scheme comprises 3 concurrent range zones which were assigned from the Early to Late Oligocene.

Haq (1971b) established 2 zones in the Malloula section, near Damascus, Syria which he assigned to the Early Eocene.

Turkey:

Toker (1989) proposed a general zonation scheme for Turkey based upon 1200 outcrop samples taken from 7 sections from a wide area of Turkey including Thrace, Zonguldak, Haymana, Kaman, Sarkisla, Antalya and two sections from Adiyaman. He defined 18 zones within the Palaeocene and Eocene succession of Turkey.

These zonation schemes from various parts of the Middle East have been correlated to the calcareous nannofossil zonation scheme proposed during this study and can be seen in Figures 2.16a-c.

6.4.2 Foraminiferal Zonation Schemes:

6.4.2 (i) Global Foraminiferal Zonation Schemes

The calcareous nannofossil zonation scheme proposed during this study has been correlated with the global planktonic foraminiferal zonation schemes of Bolli (1957a, b, 1970), Bolli and Bermudez (1965), Bolli and Permoli Silva (1973), Banner and Blow (1965), Blow (1969), and Berggren and van Couvering (1974). This was carried out by firstly correlating the calcareous nannofossil zonation scheme with the global calcareous nannofossil schemes of Martini (1971) and Okada and Bukry (1980) which have been previously correlated to global foraminiferal zonation schemes by Harland *et al.* (1989) (see Figure 2.17). These global foraminiferal zonation schemes were established using outcrop and core material, despite this advantage the calcareous nannofossil zonation scheme developed during this study provided a finer resolution for the Late Palaeocene to Early Eocene period and was as good at sub-dividing the Late Oligocene to Early Miocene period. However, the global foraminiferal zonation

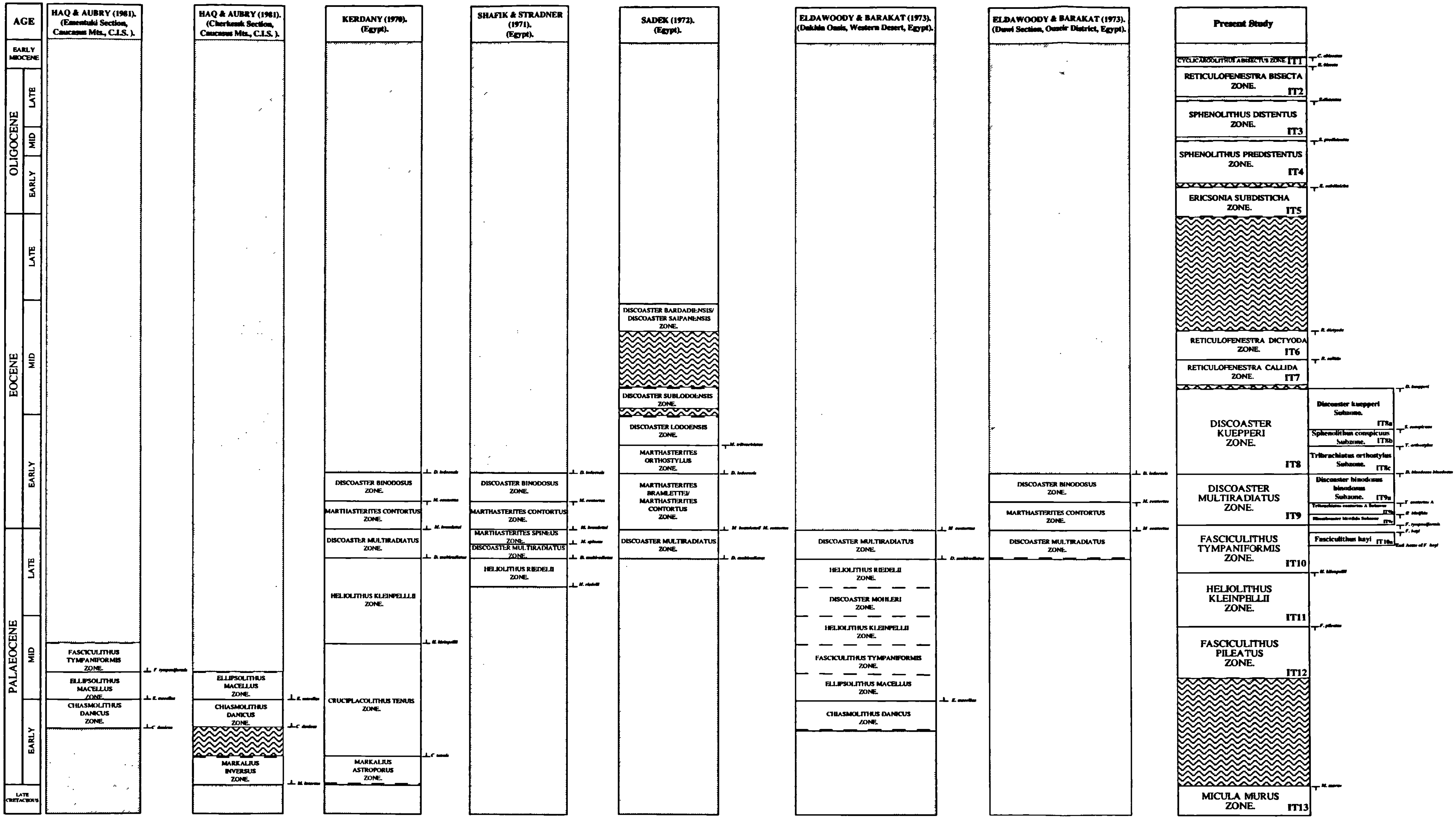

Figure 6.16a Correlation between Onshore Middle Eastern Calcareous Nannofossil Zonation Schemes and the Calcareous Nannofossil Zonation developed during this Present Study

KEY: NOT ZONED; FIRST DOWNHOLE OCCURRENCE OR LAST APPEARANCE; HIATUS; FIRST APPEARANCE

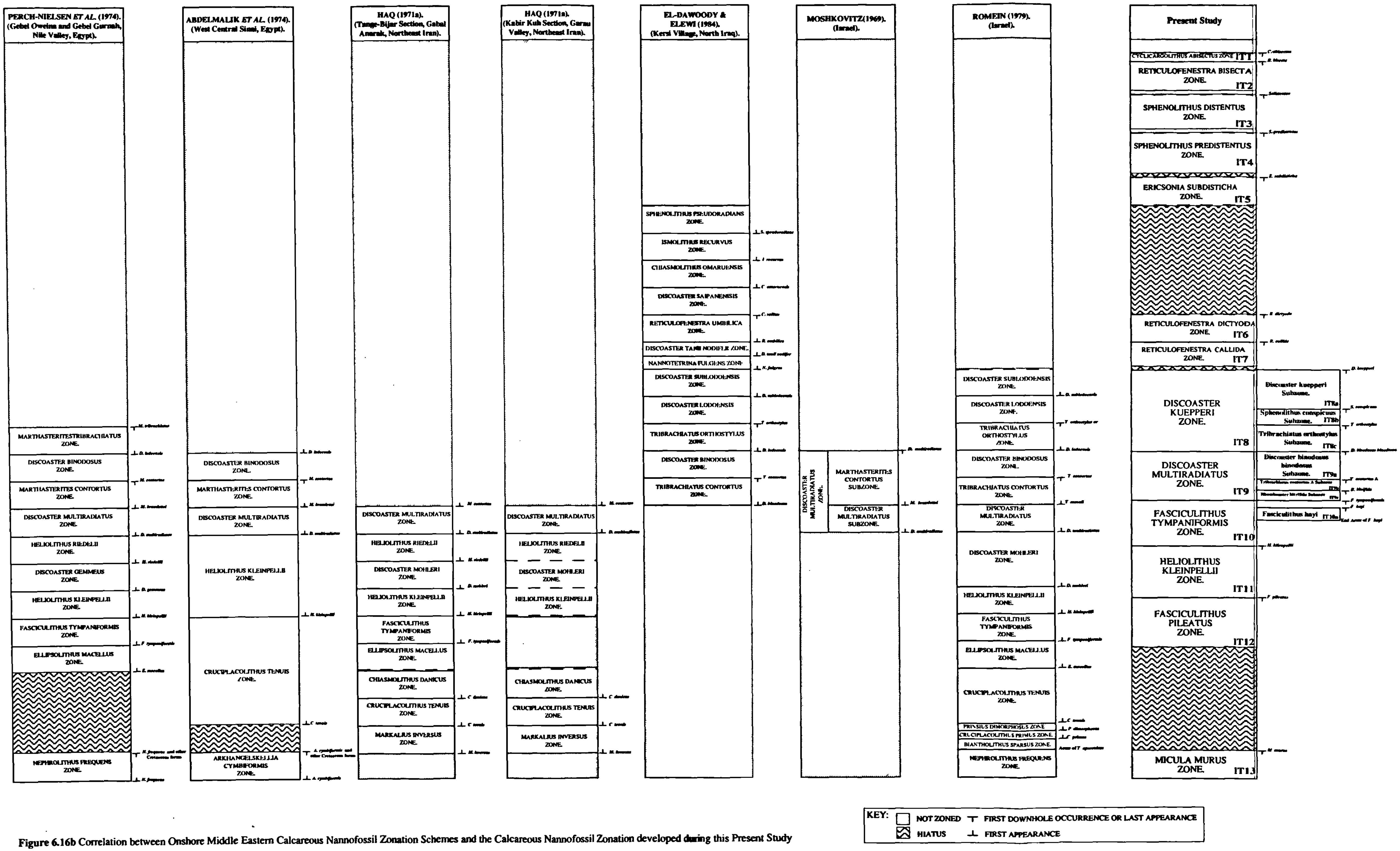

Figure 6.16b Correlation between Onshore Middle Eastern Calcareous Nannofossil Zonation Schemes and the Calcareous Nannofossil Zonation developed during this Present Study

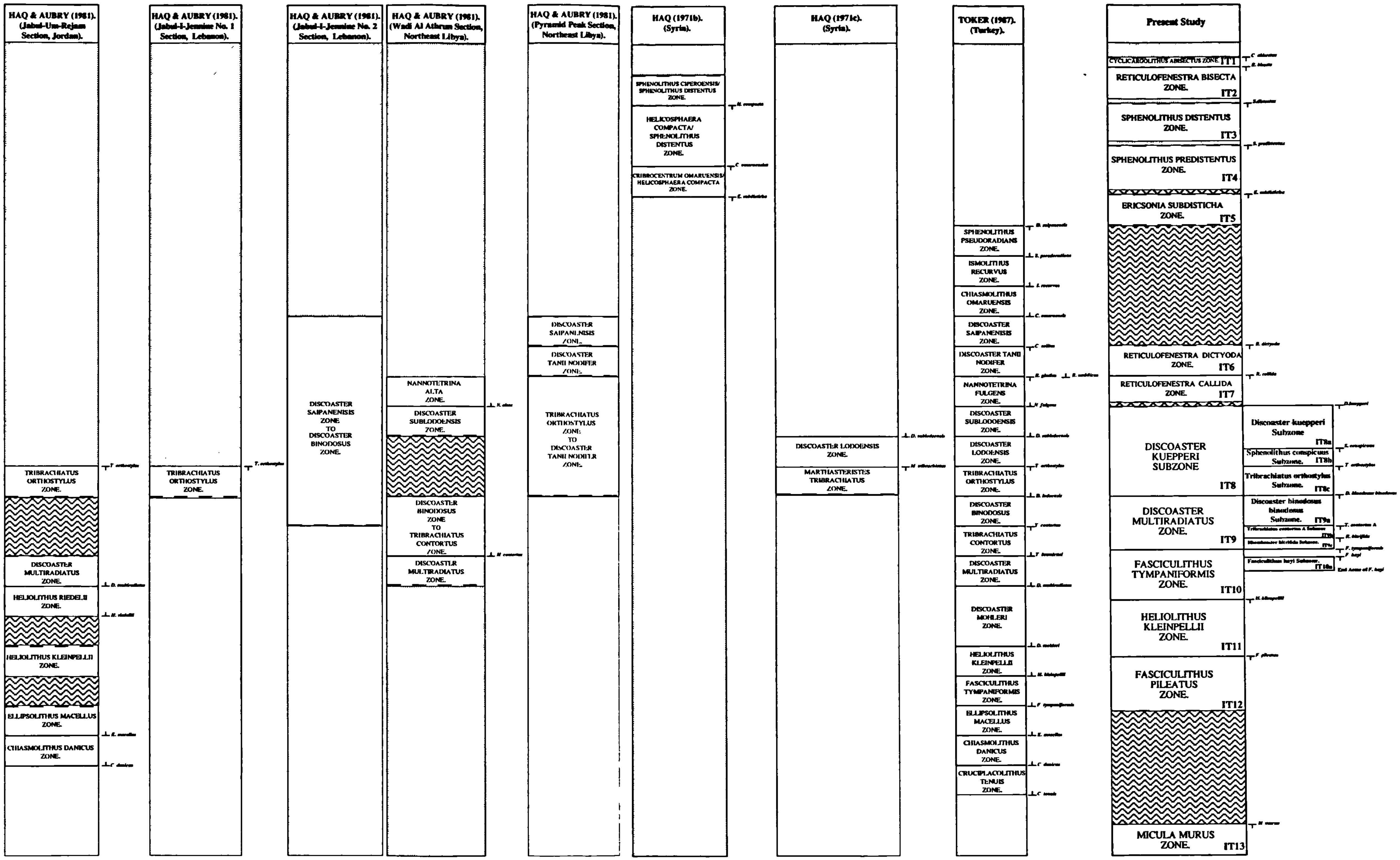

Figure 6.16c Correlation between Onshore Middle Eastern Calcareous Nannofossil Zonation Schemes and the Calcareous Nannofossil Zonation developed during this Present Study

KEY: NOT ZONED; HIATUS; ┬ FIRST DOWNHOLE OCCURRENCE OR LAST APPEARANCE; ┴ FIRST APPEARANCE

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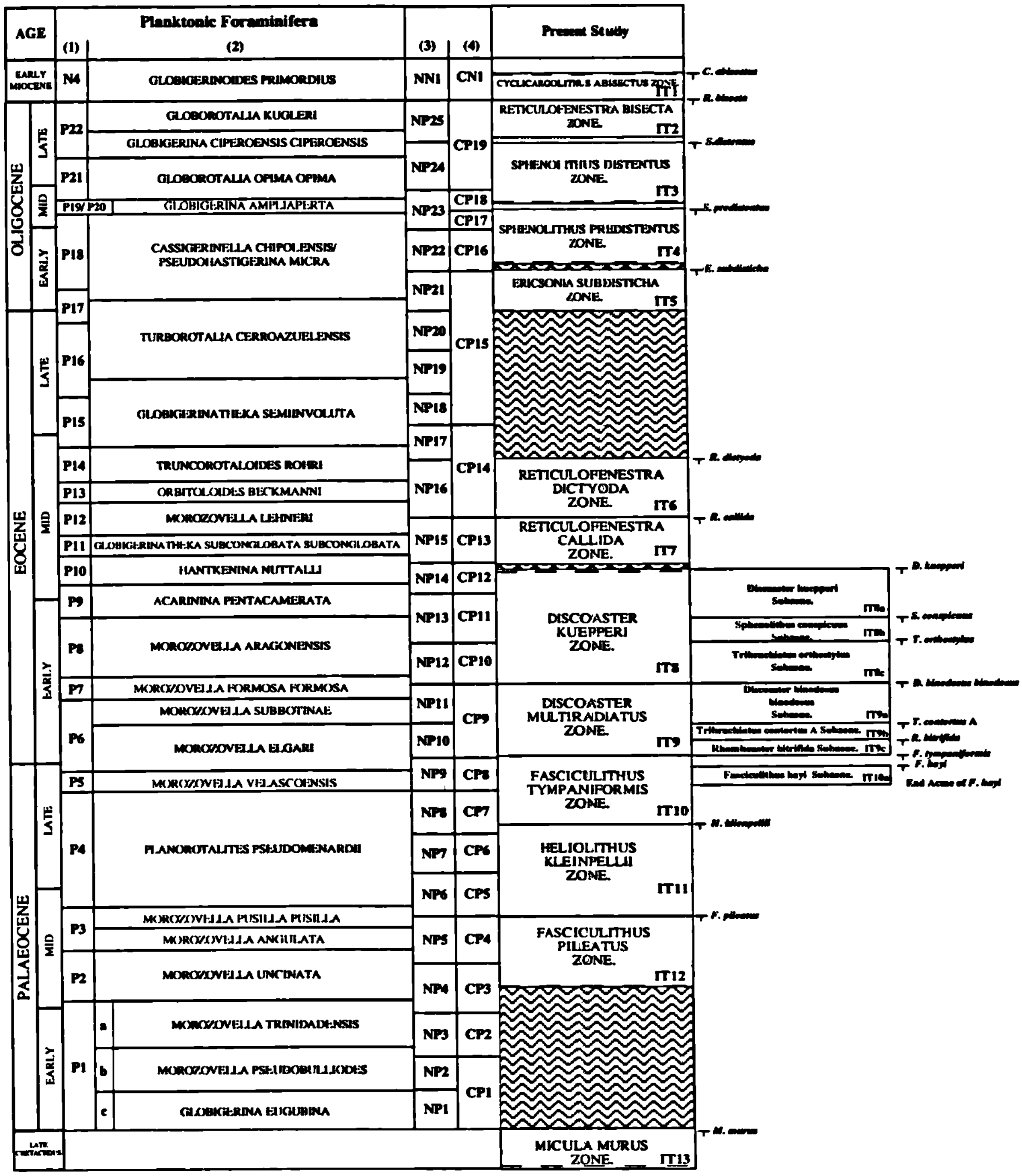


KEY:

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & Permoli Silva (1973) and Bolli & Saunders in Perch-Nielsen *et al.* (1985).

(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvenng (1974).

(3). Martini (1971).

(4). Okada & Bukry (1980).

☐ NOT ZONED

☒ HIATUS

┬ FIRST DOWNHOLE OCCURRENCE OR LAST APPEARANCE

Figure 6.17 The Calcareous Nannofossil Zonation Scheme Developed During This Present Study Correlated to Global Planktonic Foraminiferal Zonation Schemes (Partly Modified After Perch-Nielsen *et al.* 1985).

schemes provide higher resolution for the Mid and Early Oligocene and are especially useful for subdividing the Mid Eocene.

6.4.2 (ii) Regional Foraminiferal Zonation Schemes

The planktonic and benthonic foraminiferal zonation schemes established in Iraq have also been correlated with the calcareous nannofossil scheme developed during this study, using the same method outlined above.

Al-Hashimi and Amer (1985) are the only authors to-date that have produced foraminiferal zonation schemes to comprehensively cover the early Tertiary succession in Iraq, as attempted during this study. How these planktonic and benthonic foraminiferal zonation schemes correlate with the calcareous nannofossil zonation scheme developed during this study can be seen in Figure 6.18. Al-Hashimi and Amer used both outcrop and conventional core samples to establish their zonation scheme allowing the use of both first and last occurrences. Despite this advantage, the nannofossil scheme produced during this present study, using only last occurrences, enabled a finer sub-division of the Late Palaeocene to Early Eocene and the Late Oligocene to Early Miocene periods. However, Al-Hashimi and Amer's planktonic foraminiferal zonation scheme does provide a finer sub-division for the Mid Eocene and Mid Palaeocene. Al-Hashimi and Amer also recognised Late Eocene sediments, however Late Eocene sediments were not recognised in any of the 10 well sections used for this study. The benthonic foraminiferal zonation scheme of Al-Hashimi and Amer is particularly useful for sub-dividing the shallow water sediments where the calcareous nannofossils are rare or absent.

The majority of the foraminiferal work carried out in Iraq is based upon isolated well and outcrop sections and individual formations. These studies again have an advantage over the present study as they are generally based upon conventional core and outcrop material allowing the use of first and last occurrences of taxa to establish zonation schemes. Again, despite this advantage the nannofossil scheme developed during this present study provides improved stratigraphic refinement for the Early

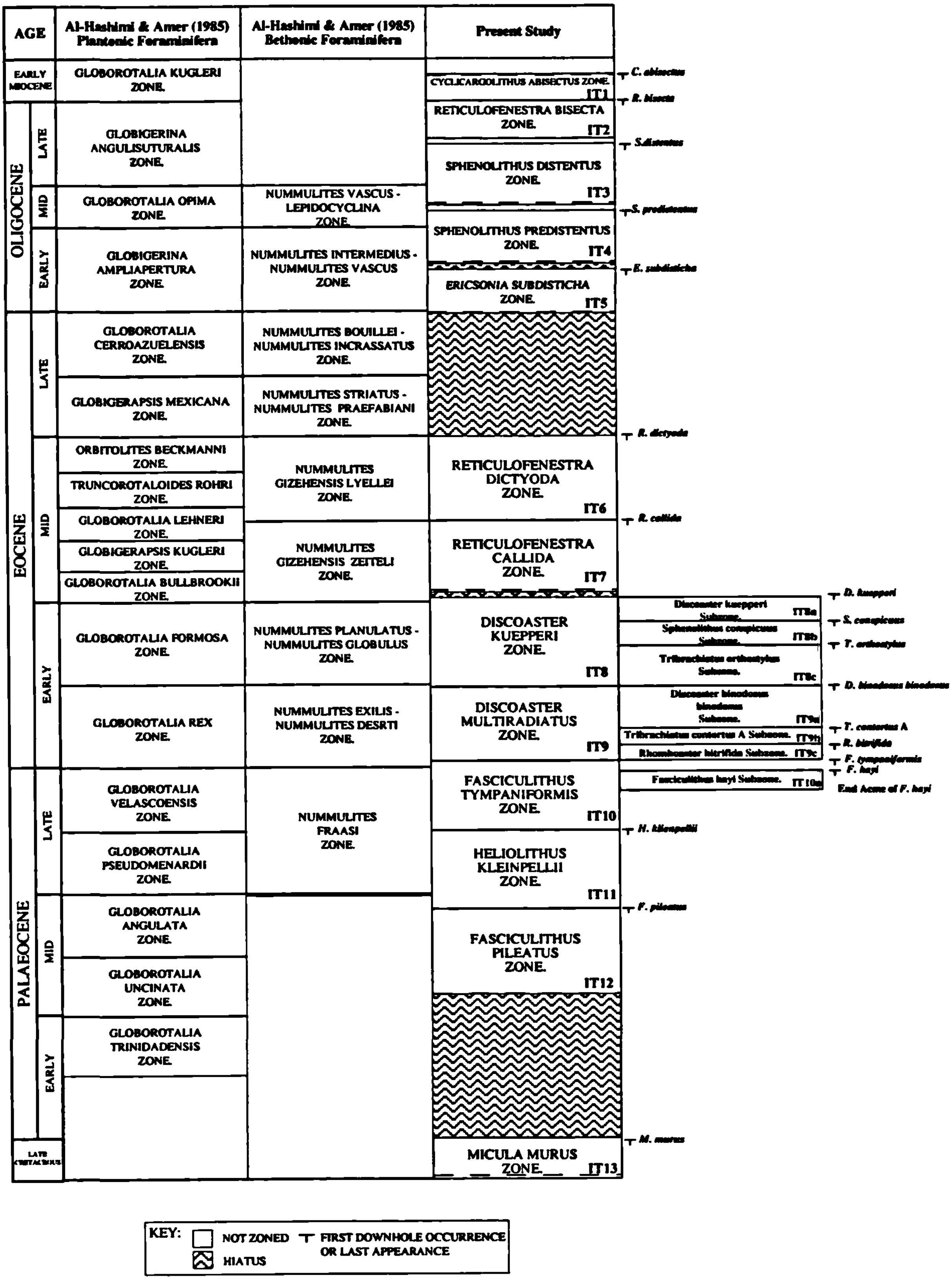


Figure 6.18 The Calcareous Nannofossil Zonation Scheme Developed During This Present Study Correlated to the Foramininferal work of Al-Hashimi & Amer (1985) for Iraq.

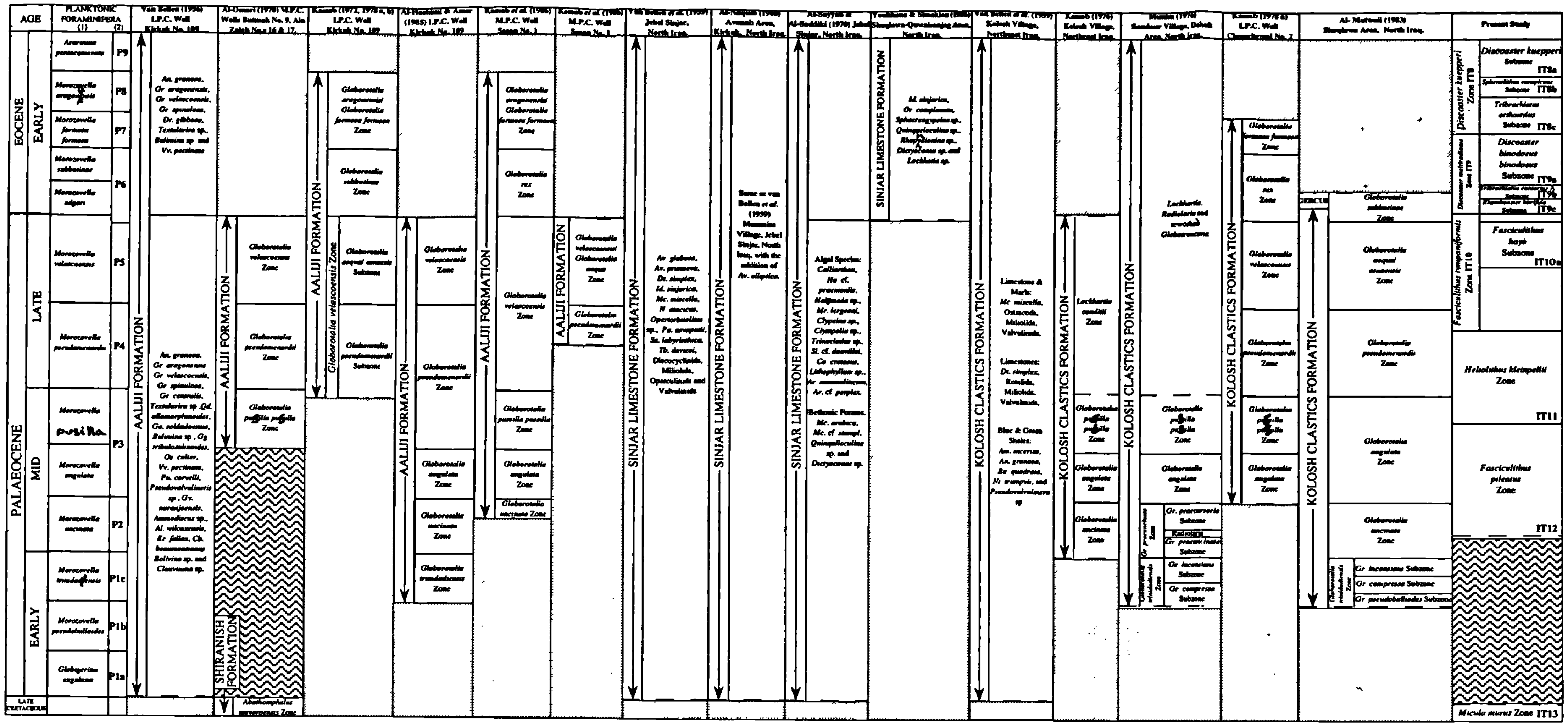
Tertiary when compared with that based upon other fossil groups. The relative merits of the various foraminiferal zonation schemes versus the nannofossil scheme developed during this study is discussed under the following time intervals: the Late Cretaceous to Early Eocene, Mid to Late Eocene, Oligocene and Early Miocene periods.

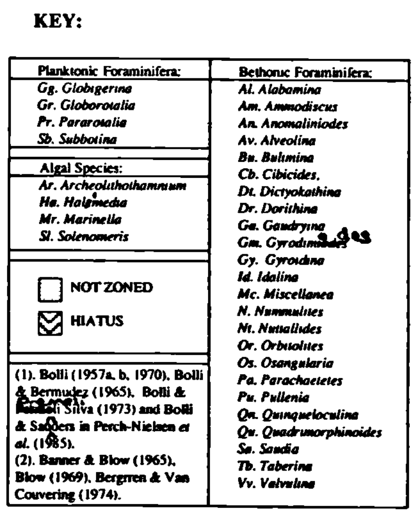
Late Cretaceous to Early Eocene.

The calcareous nannofossil scheme developed during this study correlates with the foraminiferal zonation schemes produced for the Late Cretaceous to Early Eocene period and can be seen in Figure 6.19. The zonation scheme that provides the greatest resolution for this time period is that by Kassab (1978a) for I.P.C. Well Chemchemal No. 2, which allows the direct comparison between the foraminiferal and calcareous nannofossil zonation schemes as this well section was also sampled during this present study. Kassab (1978a) based his zonation scheme on both first and last occurrences using conventional core samples from Chemchemal No. 2, however the calcareous nannofossil zonation scheme developed for this well section is based upon drill cuttings and therefore only last occurrence datums could be used to establish this zonation scheme. Despite this disadvantage, the calcareous nannofossil zonation scheme presented in this study offers higher resolution, as four zones and seven subzones were established in which Kassab (1978a) could only establish six zones and two subzones.

Mid to Late Eocene:

The scheme developed during this study correlates with the foraminiferal zonation schemes produced for the Mid to Late Eocene period and can be seen in Figure 6.20a and b. The planktonic zonation schemes that offer the highest resolution for this time period in Iraq are those by Karim & Barlette (1979) for the Jebel Gaulat area in northwest Iraq and Al-Hashimi & Amer (1986) for the well Ibrahim No. 1 also in northwest Iraq. Karim and Barlette (1979) studied a 22 metre outcrop section in the Jaddala Formation and established one zone, the *Globorotalia bullbrooki*/ *Globorotalia kugleri* Zone which they attributed to the Mid Eocene. They did not record any Late





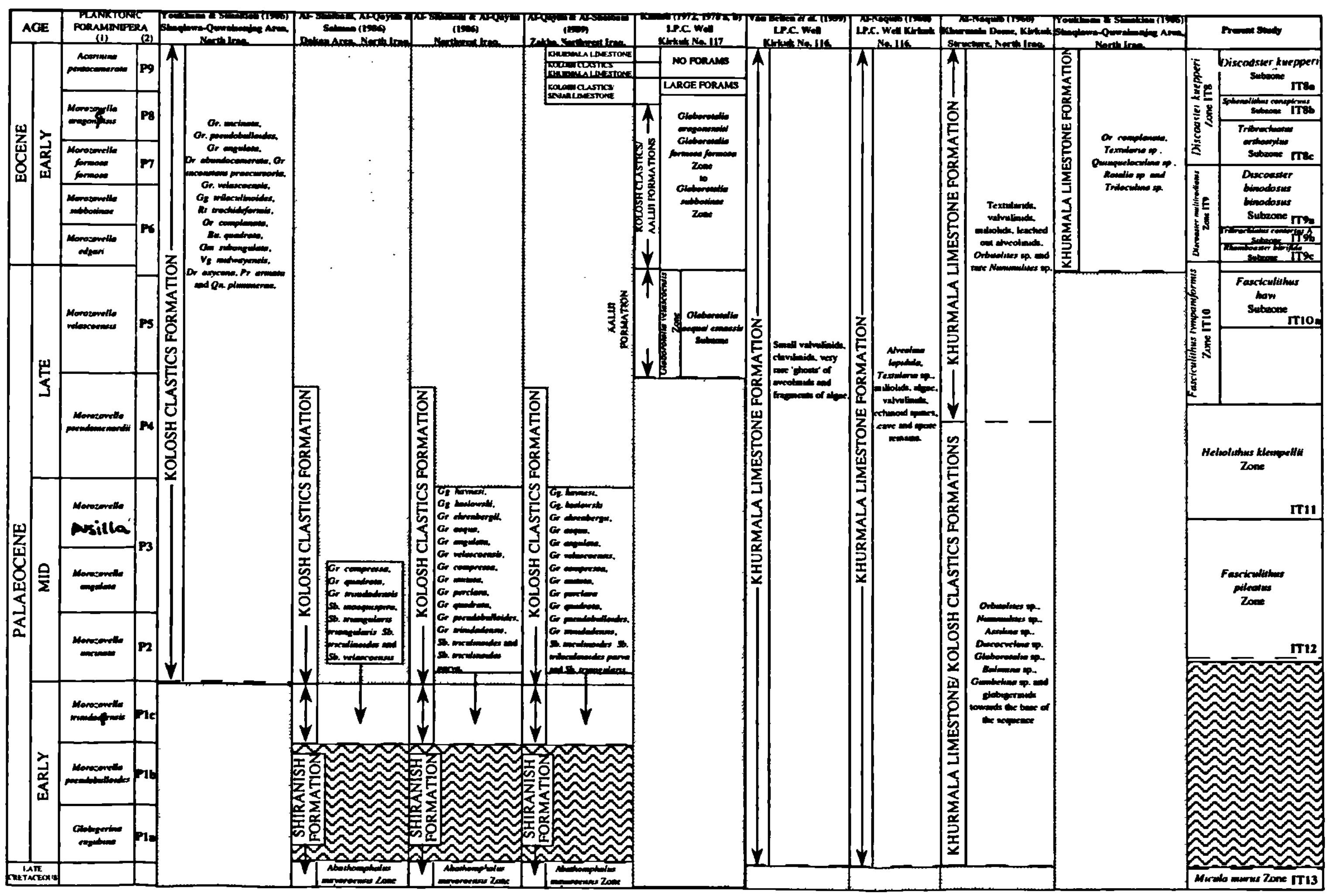
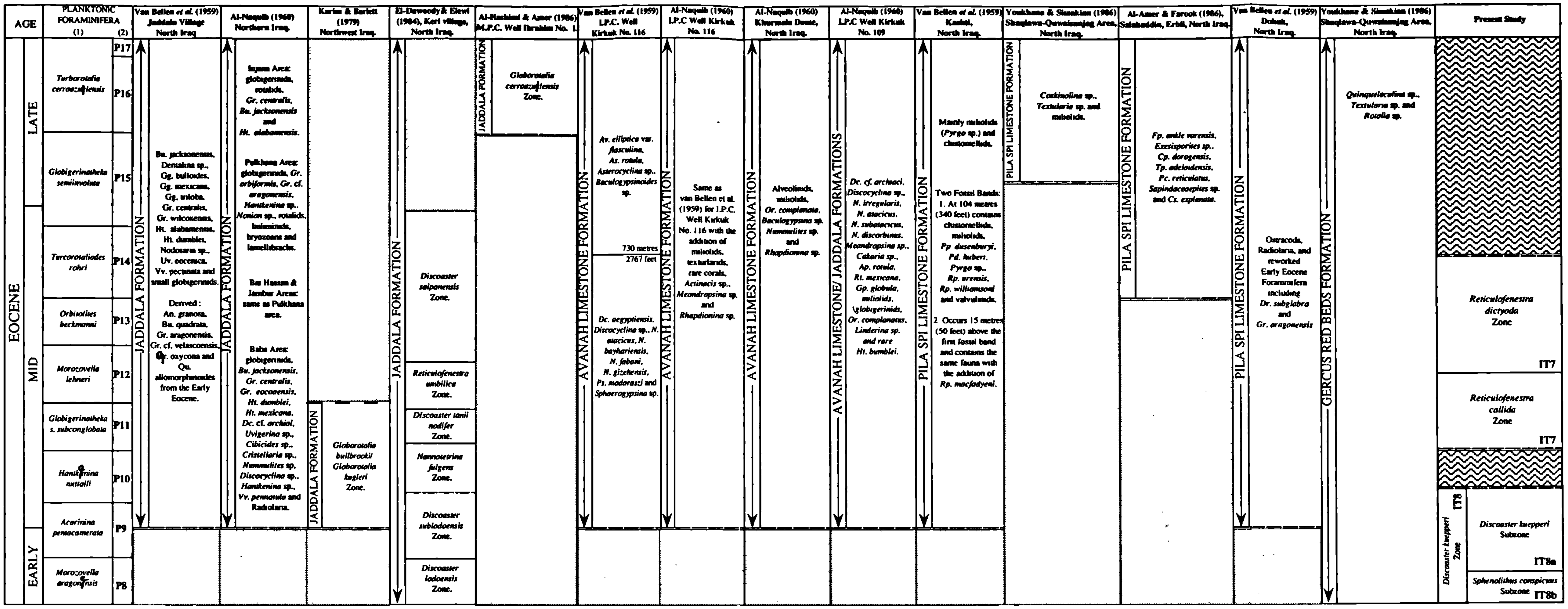


Figure 6.19 Previous Biostratigraphic Work for the Late Cretaceous to Early Eocene Succession of Northern Iraq Correlated with the Calcareous Nannofossil Zonation Scheme Devloped during this Present Study.



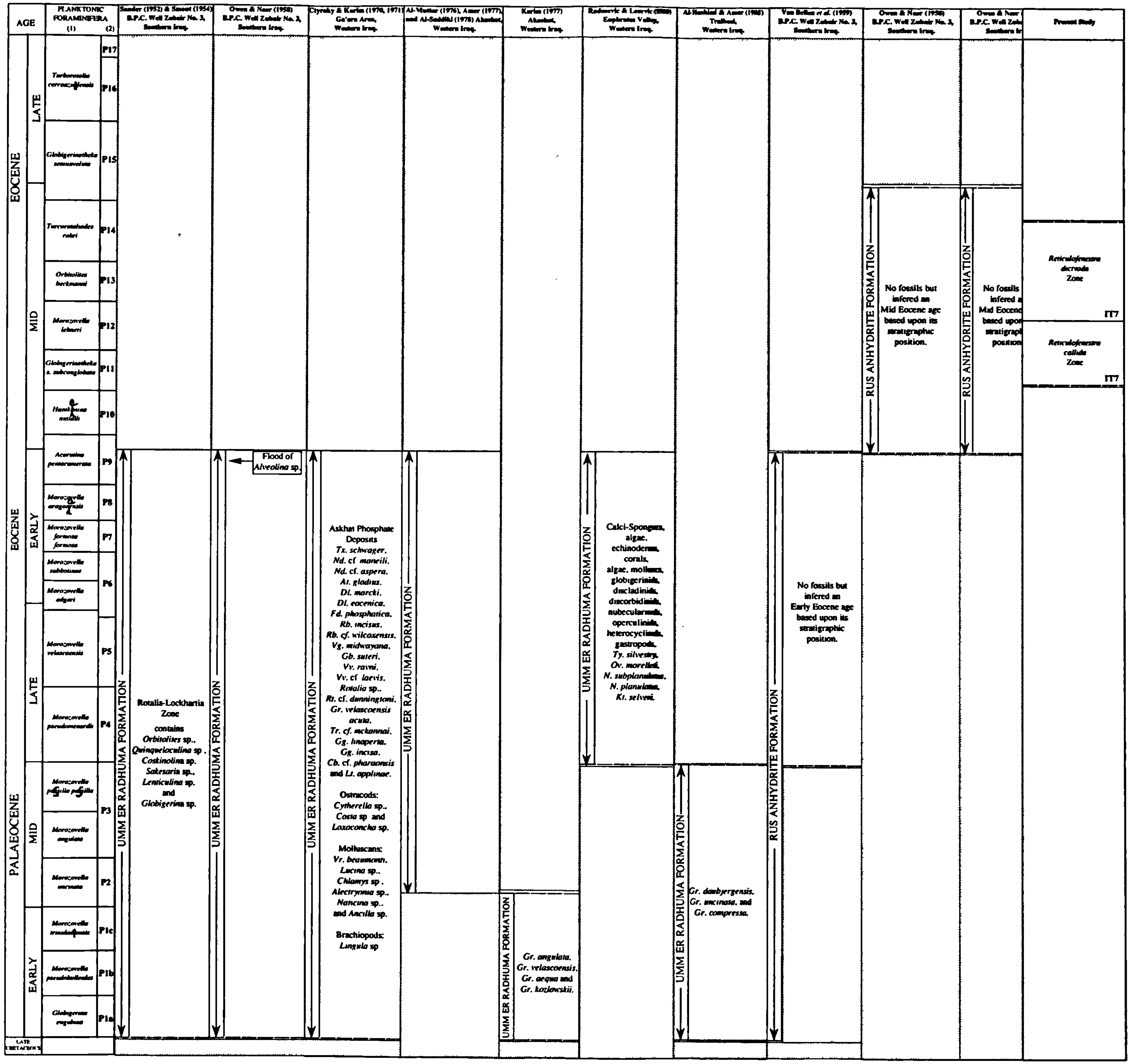
KEY:

Planktonic Foraminifera:	Benthonic Foraminifera:
Gb. Globigerapsis	*An. Anomalinoides*
Gg. Globigerina	*Ap. Amphistegina*
Gr. Globorotalia	*As. Asterigerina*
Ht. Hantkenina	*Av. Alveolina*
	Bu. Bulimina
Spore Species:	*Dc. Discocyclina*
Cp. Cicatricosporites	*Dn. Dictyoconus*
Cs. Chytroeisphaeraidae	*Dr. Dorithina*
Fp. Faveodiporites	*Gp. Gypsina*
Pc. Polycolpites	*N. Nummulites*
Tp. Tricolporites	*Or. Orbitolites*
	Pd. Praerhapidionina
	Pp. Peneroplis
NOT ZONED	*Ps. Pellatispira*
HIATUS	*Rp. Rhapidionina*
	Rt. Rotalia
	Vv. Valvulina

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & Permoli Silva (1973) and Bolli & Sauders in Perch-Nielsen *et al.* (1985).

(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvering (1974).

Figure 6.20a Previous Biostratigraphic Work for the Early to Late Eocene Succession of Northern Iraq Correlated with the Calcareous Nannofossil Zonation Scheme Developed during this Present Study.



KEY:

Planktonic Foraminifera:	Benthonic Foraminifera:
Gb. Globobulimina	*At. Astacolus*
Gg. Globigerina	*Cb. Cibicides.*
Gr. Globorotalia	*Dl. Dentalia*
Tr. Turborotalia	*Fd. Frondicularia*
	Kt. Kathina
	Lt. Loxostomum
Molluscan Species:	*N. Nummulites*
Vn. Venericardia	*Nd. Nodosaria*
	Ov. Ovulites
	Qn. Quinqueloculina
	Rb. Robulus
NOT ZONED	*Rt. Rotalia*
HIATUS	*Tx. Textularia*
	Ty. Tyrsoporella
	Vg. Vagulina
	Vv. Valvulina

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & ~~Bermudez~~ Silva (1973) and Bolli & Saunders in Perch-Nielsen *et al* (1985). Premoli

(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvering (1974).

Figure 6.20b Previous Biostratigraphic Work for the Palaeocene to Mid Eocene Succession of Southern Iraq Correlated with the Calcareous Nannofossil Zonation Scheme Developed during this Present Study.

Eocene sediments but suggested that Early Oligocene sediments are unconformable upon the Jaddala Formation. Al-Hashimi & Amer (1986), only sampled the very top of the Jaddala Formation in the Ibrahim No. 1 well section but, established the *Globorotalia cerioazulensis* Zone which they attributed to the Late Eocene. During this present study two nannofossil zones, the *Reticulofenestra callida* and *Reticulofenestra dictyoda* Zones were established and attributed to the Mid Eocene. In all, 4 well section containing the Jaddala Formation have been studied (Atshan No.1, Kirkuk No. 85, Pulkhana No. 5 and Musaiyib No. 1); the Late Eocene was not in any of the four wells.

Oligocene to Early Miocene:

The nannofossil scheme developed during this study correlates with the foraminiferal zonation schemes produced for the Oligocene to Early Miocene period and can be seen in Figures 6.21 and 6.22.

The planktonic foraminiferal zonation scheme that provides the highest resolution for this time period is that of Al-Hashimi and Amer (1986) produced for the Early Oligocene based upon conventional core samples from the well Ibrahim No. 1 in northwest Iraq. They recognised one planktonic foraminiferal zone for the Early Oligocene, the *Cassigerinella chipolensis/ Globanomalina micra* Zone. During this present study one calcareous nannofossil zone was assigned to the Early Oligocene time interval, the *Ericsonia subdisticha* Zone.

The most reliable planktonic foraminiferal zonation scheme previously produced for the Mid Oligocene of Iraq is again that of Al-Hashimi & Amer (1986) from the same well section. They recognised one planktonic foraminiferal zone for the Mid Oligocene time interval, the *Globorotalia opima opima* Zone. Similarly in this present study only one nannofossil zone could be assigned to the Mid Oligocene, the *Sphenolithus predistentus* Zone.

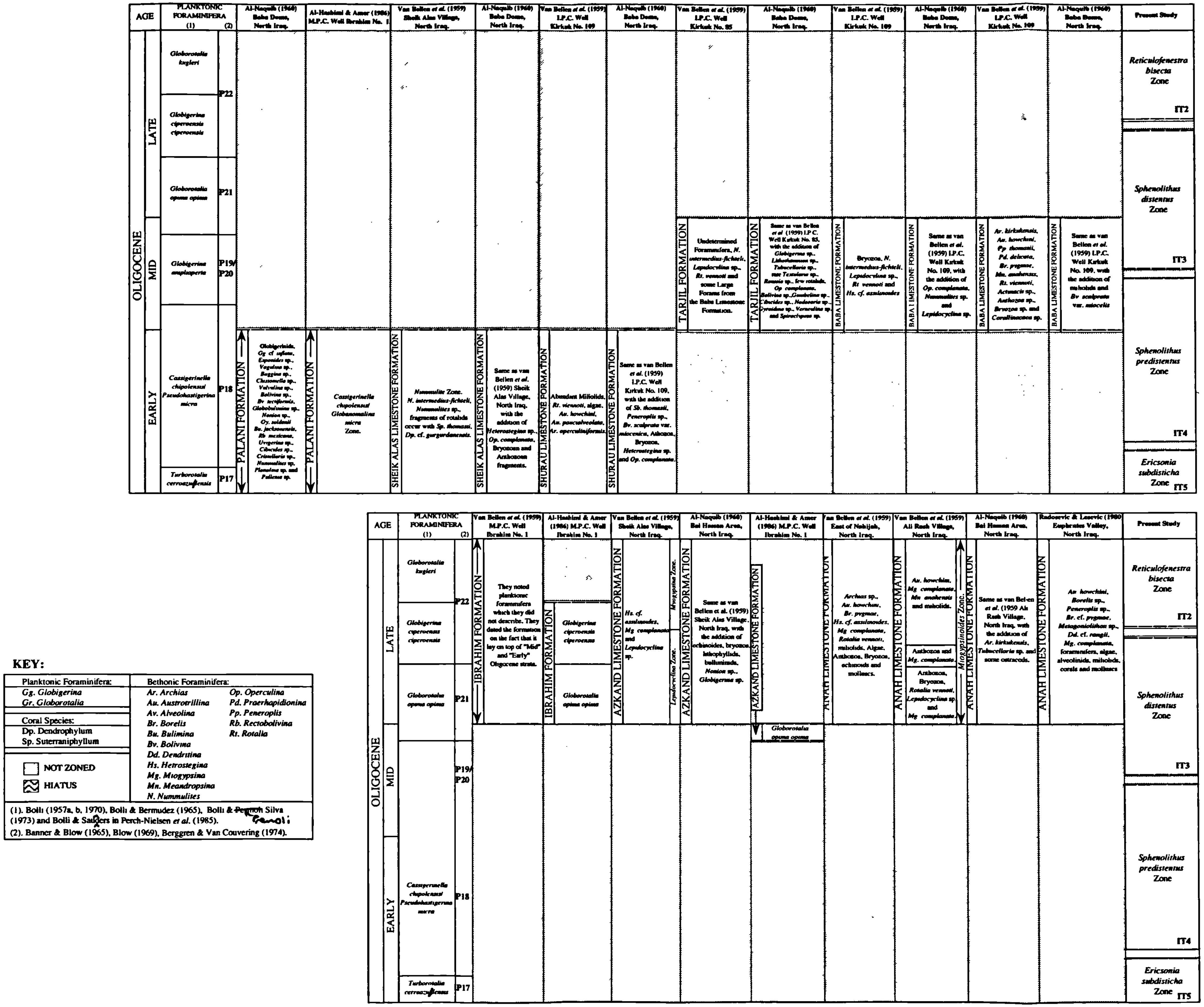
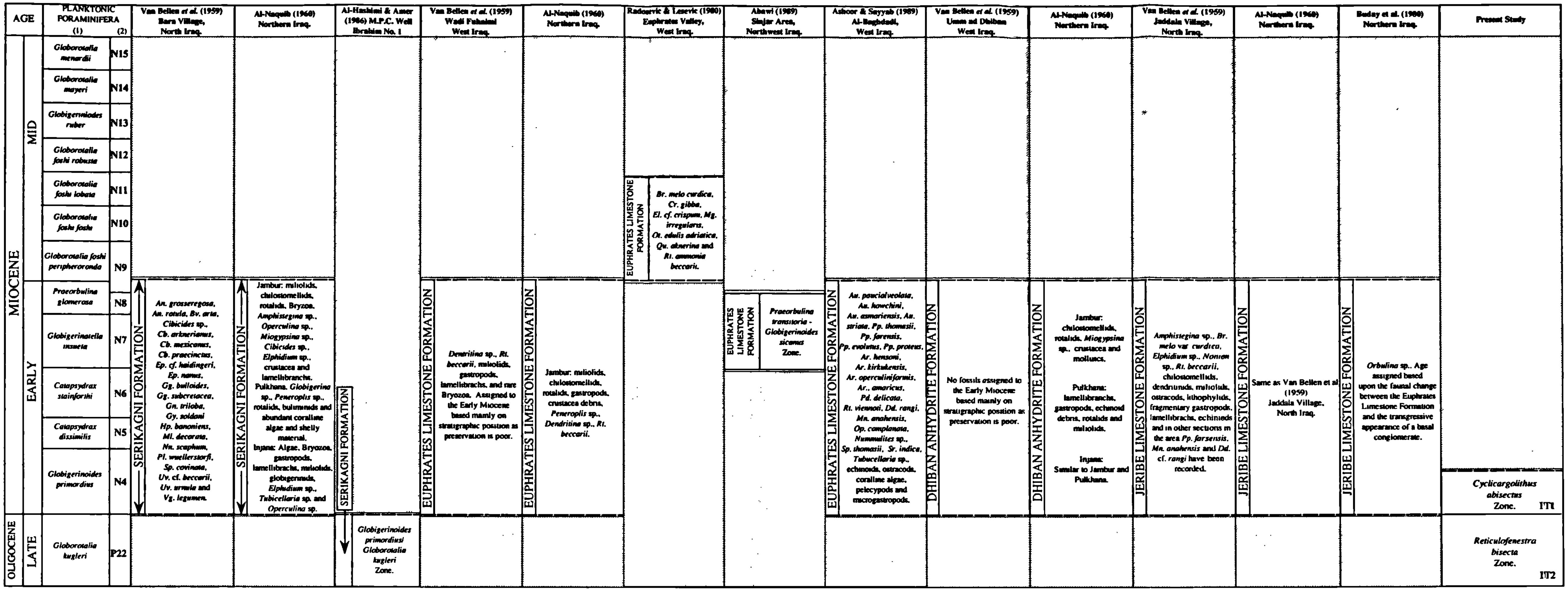


Figure 6.21 Previous Biostratigraphic Work for the Oligocene Succession of Northern Iraq Correlated with the Calcareous Nannofossil Zonation Scheme Developed during this Present Study.



KEY:

Planktonic Foraminifera:	Benthonic Foraminifera:	
Gg. Globigerina	*An. Anomalina*	*Mg. Miogypsina*
Gn. Globigerinoides	*Ar. Archias*	*Ml. Marginula*
Gr. Globorotalia	*Au. Austrotrillina*	*Mn. Meandropsina*
	Av. Alveolina	*Nn. Nonion*
	Br. Borelis	*Op. Operculina*
Coral Species:	*Bu. Bulimina*	*Ot. Ostrea*
Dp. Dendrophylum	*Bv. Bolivina*	*Pl. Planulina*
Sp. Suterraniphyllum	*Cb. Cibicides*	*Pd. Praerhapidionina*
	Dd. Dendritina	*Qu. Quinqueloculina*
	El. Elphidium	*Pp. Peneroplis*
NOT ZONED	*Ep. Eponides*	*Rb. Rectobolivina*
	Gy. Gyroidina	*Rt. Rotalia*
HIATUS	*Hp. Hopkinsina*	*Uv. Uvigerina*
	Hs. Hetrostegina	*Vg. Vagulina*

(1). Bolli (1957a, b, 1970), Bolli & Bermudez (1965), Bolli & ~~Remoli~~ Premoli Silva (1973) and Bolli & Saunders in Perch-Nielsen *et al.* (1985).
(2). Banner & Blow (1965), Blow (1969), Berggren & Van Couvering (1974).

Figure 6.22 Previous Biostratigraphic Work for the Late Oligocene to Mid Miocene Succession of Northern Iraq Correlated with the Calcareous Nannofossil Zonation Scheme Developed during this Present Study.

6.0 Biostratigraphy

The most reliable planktonic foraminiferal zonation scheme previously produced for the Late Oligocene to Early Miocene period is again that of Al-Hashimi & Amer (1986) from the well Ibrahim No. 1 in northwest Iraq. They assigned only two planktonic foraminiferal zones to this time interval, the *Globigernna angulisuturalis* and *Globigerinoides primordius/ Globorotalia kugleri* Zones. However, during this present study three nannofossil zones were established for the same time interval, the *Sphenolithus distentus* (IT3), the *Reticulofenestra bisecta* (IT2) and the *Cyclicargolithus abisectus* (IT1) Zones, therefore enabling improved stratigraphic subdivision.

Although the calcareous nannofossil zonation scheme presented during this study is largely based upon the examination of drill cuttings it does enable a higher degree of stratigraphic resolution to be achieved than that based upon planktonic foraminifera. Several intervals examined during this study proved to be devoid of calcareous nannofossils, but do contain abundant nummulitic faunas. For these intervals it may well be possible to establish a zonation scheme based upon benthonic foraminifera perhaps using the benthonic foraminiferal zonation scheme developed by Al-Hashimi and Amer (1985) as a basis.

6.4.2 (iii) The Magnetobiochronologic Timescale.

The Cenozoic magnetobiochronology of Berggren *et al.* (1985 a, b, c) has to date been widely used to translate biostratigraphic information into numerical information for calculating sedimentation rates and the duration of periods of non-deposition. However the geomagnetic polarity time scale has recently been improved by Cande and Kent (1992), and this work was used by Wei and Peleo-Alampay (1993) to re-calculate the magnetobiochronologic ages proposed by Berggren *et al.* (1985) for the first and last occurrence datums (F.A.D.'s and L.A.D's) of the Cenozoic nannofossil schemes of Martini (1971) and Okada and Bukry (1980).

This improvement in accuracy in calculating the magnetobiochronologic ages was used in this study to calibrate the first down hole occurrences (F.D.O.'s) or L.A.D's of the marker species used in establishing the calcareous zonation scheme (see Figure 6.23). This timescale was used as no other suitable scheme was available for or in the vicinity of the study area. However, as stated earlier the marker species of Martini (1971) and Okada and Bukry (1980) were not exclusively used in the study area, and therefore the only marker species that could be directly calibrated to the absolute ages re-calculated by Wei and Peleo-Alampay (1993) are; the L.A.D.'s of *Micula murus*, *Fasciculithus tympaniformis*, *Tribrachiatus contortus*, *Tribrachiatus orthostylus*, *Sphenolithus predistentus* and *Sphenolithus distentus*. The other zones in the calcareous zonation scheme established in Iraq, were calibrated to the magnetostratigraphic timescale by firstly relating the zones to the calcareous nannofossil zonation scheme proposed by Martini (1971), and then reading off the corresponding absolute ages for that zone. This method, though inaccurate does allow estimations of the amount of subsidence and the timing of uplift events that occurred in the study area during the Mid Palaeocene to Early Miocene period. This information is discussed in the next chapter.

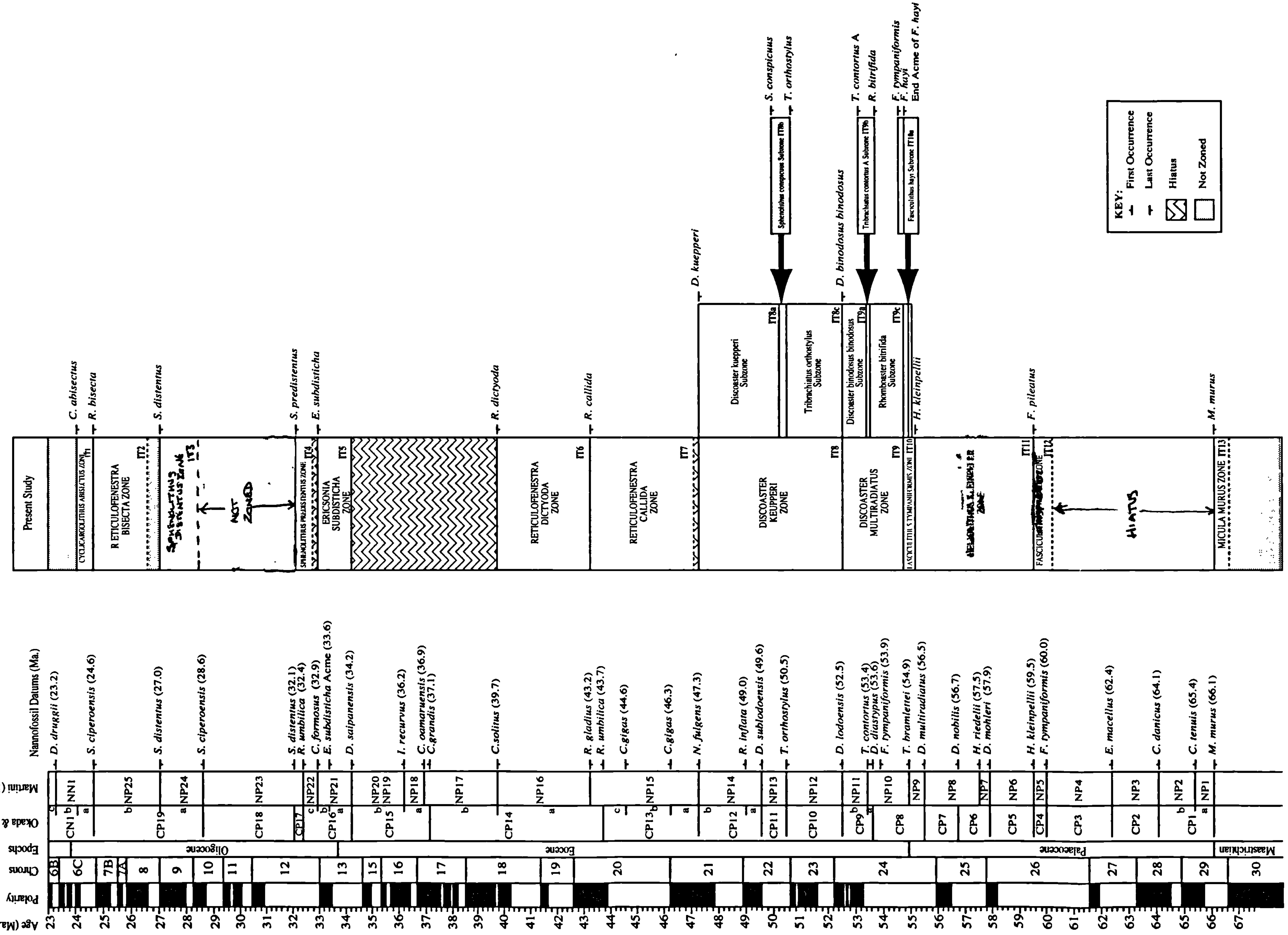


Figure 6.23 Correlation of Calcareous Nannofossil Zonation Scheme Proposed During this Present Study with the Magnetobiochronologic Timescale (Partly After Wei & Peleo-Alampay 1993).

CHAPTER SEVEN
DISCUSSION

7.1 Subsidence and Uplift History:

7.1.1 Introduction:

The amounts of subsidence and the periods of uplift have been calculated for the study area by calibrating the First Down Occurrences (F.D.O.'s) or Last Appearance Datums (L.A.D.'s) of marker species used in establishing the calcareous nannofossil zonation scheme in Iraq, to the standard magnetobiostratigraphic time scale. The method used to carry out this calibration and the calculation of subsidence rates is outlined in Chapter Six Biostratigraphy under section 6.4.2 (iii) The Magnetobiochronologic Timescale.

7.1.2 Mid Palaeocene - Early Eocene:

The subsidence history during this time period is illustrated in Figure 7.1. The zones and subzones established for this time period are listed below:

***Discoaster kuepperi* Zone:**	***Discoaster kuepperi* Subzone.**
	***Sphenolithus conspicuus* Subzone.**
	***Tribrachiatus orthostylus* Subzone.**
***Discoaster multiradiatus* Zone:**	***Discoaster binodosus binodosus* Subzone.**
	***Tribrachiatus contortus* A Subzone.**
	***Rhomboaster bitrifida* Subzone.**
***Fasciculithus tympaniformis* Zone:**	***Fasciculithus hayi* Subzone.**
***Heliolithus kleinpellii* Zone.**	
***Fasciculithus pileatus* Zone.**	

This sequence of zones is unconformable upon the Late Cretaceous succession, the unconformity spans a minimum 3.7 Ma. and a maximum of 6.1 Ma.. The minimum age span is believed to be less likely as only the top of NP4/ CP3 is represented in the *Fasciculithus pileatus* Zone. This unconformity is probably the result of the tectonic processes active during the failed closure of the Tethys ocean during the Late Cretaceous, though the global sea-level fall at the Cretaceous/ Tertiary boundary probably initially aided the development of the unconformity.

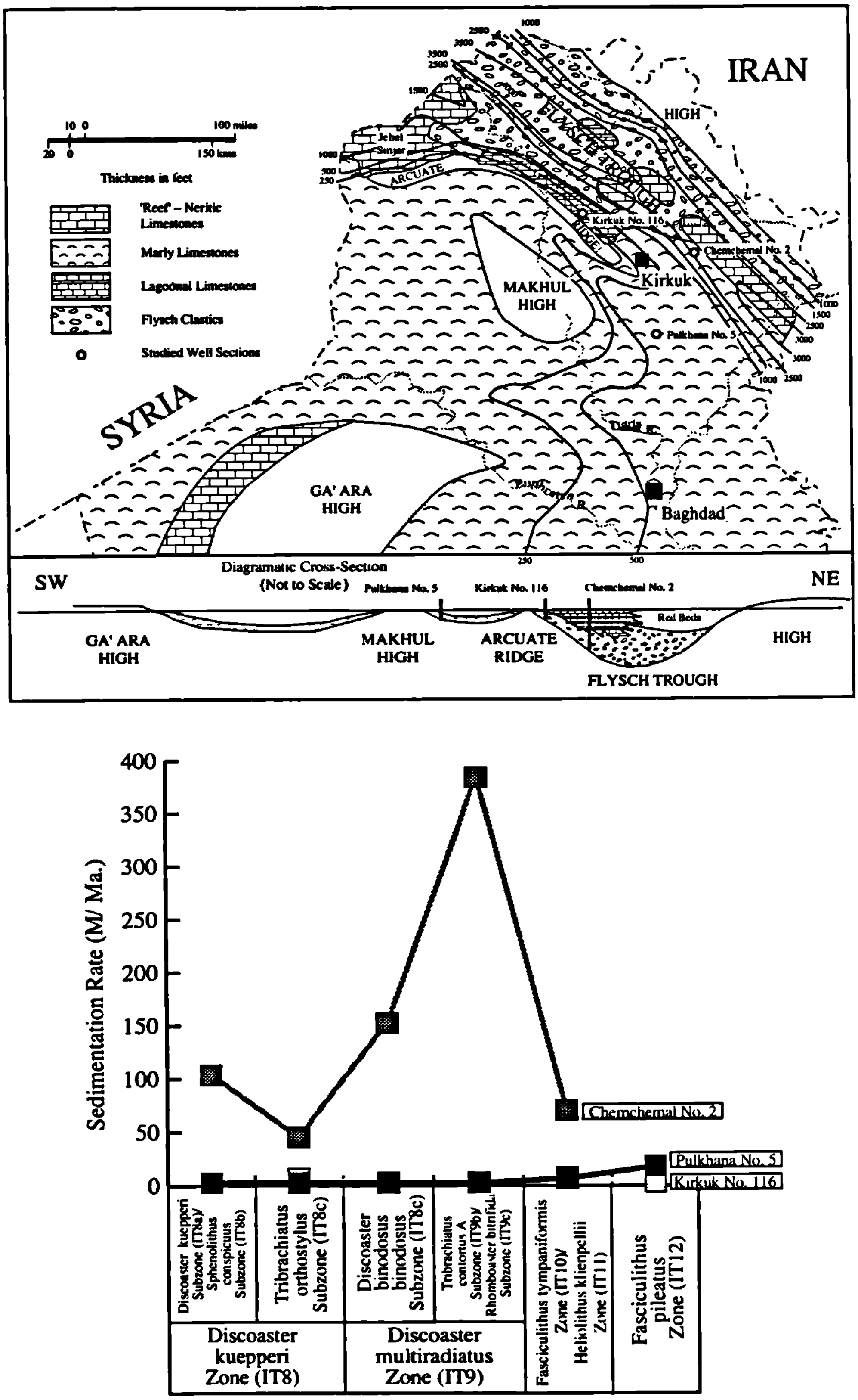


Figure 7.1 Isopach-Facies Map, Model and Sedimentation Rate Data for the Mid Palaeocene to Early Eocene of Northern Iraq (Partly Modified after Dunnington, 1958).

7.1.2 (i) *Fasciculithus pileatus* Zone (Mid Palaeocene NP4 - NP5/ CP3 - CP4):

This zone has been recognised in two well sections in northern Iraq, Pulkhana No. 5 and Kirkuk No. 116. This zone does not occur in the Chemchemal No. 2 well section though reworked components of this zone do occur in overlying zones higher up in its deposited sequence of sediments. The sedimentation rate varies between the two sections; in Pulkhana No. 5 the rate is at 54.86 M/ Ma against the 3.25 M/ Ma. in Kirkuk No. 116. The high subsidence rate in Pulkhana No. 5 is misleading and can be explained by the fact that the majority of the zone probably represents a reworked horizon occurring between the Late Cretaceous and Mid Paleocene, and not the *Fasciculithus pileatus* Zone. It is believed that only Sample No. Pu-5/ 42 truly represents this zone as below this sample the section is reworked. The reworking is recognised in the samples below Pu-5/ 42 as they are dominated robust solution resistant Cretaceous forms, *Micula staurophora* and *Watznaueria* spp. (see Abundance Diagram for Pulkhana No. 5 in Appendix A). The true sedimentation rate for the *Fasciculithus pileatus* Zone in Pulkhana No. 5 is therefore approximately 18.28 M/ Ma. The differing rates of sedimentation between Pulkhana No. 5 and Kirkuk No. 116 probably relates to the fact that Kirkuk No. 116 lies on a relatively high point in the basin at this time in relation to Pulkhana No. 5 (see Figure 7.1).

7.1.2 (ii) *Heliolithus kleinpellii* and *Fasciculithus tympaniformis* Zones (Late Palaeocene to Earliest Eocene NP6 - NP10/ CP5 - CP9a):

These zones are recognised in Pulkhana No. 5, Kirkuk No. 116 and Chemchemal No. 2. The subsidence rate increases towards Chemchemal No. 2; the rate being 6.80 M/ Ma. at Pulkhana No. 5, 8.24 M/ Ma. at Kirkuk No. 116 and 70.61 M/ Ma. at Chemchemal No. 2. Van Bellen *et al.*, (1959) previously described the centre of the basin as being sediment starved. The increase in sedimentation rate away from the centre of the basin detected during this study supports this opinion. The increase in sedimentation rate exhibited in Kirkuk No. 116 may also reflect the fact the well section is nearer to a major flysch trough being situated behind some emergent barriers both of which may act to stop the direct flow of sediment charged waters, setting up the sediment starved conditions in the centre of the basin. The major increase in the sedimentation rate in Chemchemal No. 2 is a reflection of the fact the well section is in a relatively rapidly subsiding flysch trough which runs northwest - southeast across northern Iraq, and in which both pelagic sediments and sediments derived from a positive high rising to the northeast were deposited (see Figure 7.1).

7.1.2 (iii) *Discoaster multiradiatus* Zone (Early Eocene NP10 - NP11/ CP9a - CP9b):

This zone is recorded in Kirkuk No. 116 and Chemchemal No. 2 in the study area. However, the *Discoaster multiradiatus* Zone (IT9) could not be differentiated from the *Discoaster kuepperi* Zone (IT8) in Pulkhana No. 5 as the section is condensed. The condensed nature of the Pulkhana No. 5 well section during this time period again illustrates the sediment starved nature of the centre of the basin. The sedimentation rate varies from 2.82 M/ Ma. in Pulkhana No. 5, to 3.26 M/ Ma. in Kirkuk No. 116 and averages 235.13 M/ Ma. in Chemchemal No. 2. The relatively low sedimentation rate in Kirkuk No. 116 is due to the fact the zone has probably been reworked into the *Tribrachiatus orthostylus* Subzone above. The sedimentation rate in Chemchemal No. 2 within flysch trough shows a very rapid increase to an average of 286.51 M/ Ma. during the deposition of the *Discoaster multiradiatus* Zone (IT9). However this sedimentation rate does not reflect the full picture as the *Discoaster multiradiatus* Zone (IT9) can be subdivided into three subzones in Chemchemal No. 2; *Discoaster binodosus binodosus* Subzone (IT9a), *Tribrachiatus contortus* A Subzone (IT9b) and *Rhomboaster bitrifida* Subzone (IT9c), the latter two subzones makes up the NP10 zone and the upper zone represents NP11 zone of Martini (1971). The sedimentation rate was higher during the deposition of the *Tribrachiatus contortus* A Subzone and the *Rhomboaster bitrifida* Subzone (IT9c) at 384.04 M/ Ma., while during the deposition of the *Discoaster binodosus binodosus* Subzone (IT9a) the sedimentation rate was 152.4 M/ Ma. . This rapid increase in sedimentation in the flysch trough noted in Chemchemal No. 2, during the deposition of the *Discoaster multiradiatus* Zone (IT9) around 53.9 Ma. to 52.5 Ma., may be reflecting a period of more rapid uplift of the high to the northeast, resulting in an increased supply of sediment. This increased supply of sediment was at its peak during the deposition of the *Tribrachiatus contortus* A Subzone (IT9b) and the *Rhomboaster bitrifida* Subzone (IT9c) at around 53.4 Ma to 53.9 Ma., perhaps indicating that the high was rising more rapidly during this period as a result of tectonic processes linked to the closure of Tethys ocean at this time (see Figure 7.1).

7.1.2 (iv) *Tribrachiatus orthostylus* Subzone (Early Eocene NP12/ CP10):

The *Tribrachiatus orthostylus* Subzone is recognised in Kirkuk No. 116 and Chemchemal No. 2. The *Tribrachiatus orthostylus* Subzone cannot be individually recognised in Pulkhana No. 5 due to the condensed nature of the well section, instead the subzone which is part of the *Discoaster kuepperi* Zone (IT8) occurs in conjunction with the *Discoaster multiradiatus* Zone (IT9), this again reflects the reduced sediment supply towards the centre of the basin. The sedimentation rate generally increases towards the flysch trough, Pulkhana No. 5 has a sedimentation rate of 2.82 M/ Ma, Kirkuk No. 116 has a minimum sedimentation rate of 6.86 M/ Ma., and Chemchemal No. 2 has a sedimentation rate of 45.72 M/ Ma. . In Kirkuk No. 116 the quoted sedimentation rate is a minimum rate since samples were unavailable for study from the upper part of the zone. As stated earlier the low sedimentation rate in Pulkhana No. 5 again reflects the sediment starved nature of the basin centre, and is probably low as the majority of sediments entering the basin from the high towards the northeast of Iraq at this time went to fill the flysch trough. In addition the highs within the basin probably acted to restricted the flow of sediment charged waters leading to sediments being deposited behind the highs stopping sediments entering the central parts of the basin. The Kirkuk No. 116 well section shows a marked increase in sedimentation rate, this is probably due to the fact that the Kolosh Clastics that fill the flysch trough have spilled over the basin confines during the deposition of the *Tribrachiatus orthostylus* Subzone between 50.5 Ma and 52.5 Ma., being deposited on the southern edge of the flysch trough, and being detected for the first time in the Kirkuk No. 116 well section. However, the spill over of sediments was not great enough so that the Kolosh Clastics Formation is detected as far south as Pulkhana No. 5, which lies further towards the centre of the basin. The sedimentation rate in

Chemchemal No. 2 during this time period has decreased but was still high enough to cause sediments to spilled over the edge of the flysch trough. This is probably the result of a delayed response to the high sedimentation rates previously recorded indicating that the flysch trough was not subsiding fast enough to cope with more sediment input even at a slower rate, and this is why the Kolosh Clastics Formation occurs in Kirkuk No. 116 well section, outside the confines of the flysch trough on its southern margin. The marked reduction in sedimentation rate noted in Chemchemal No. 2 is probably a reflection of a slowing down in the rise of the high in the northeast (see Figure 7.1).

7.1.2 (v) *Discoaster kuepperi* and *Sphenolithus conspicuus* Subzones (Early Eocene NP13 -NP14/ CP11 - CP12a):

The *Discoaster kuepperi* and *Sphenolithus conspicuus* Subzones are found in the Chemchemal No. 2 well section only, but the *Discoaster kuepperi* and *Discoaster multiradiatus* Zones do occur in a condensed section in the Pulkhana No. 5 well section. The Pulkhana No. 5 well section is condensed due to the fact that much of the sediment input into the area from the northeast of Iraq is deposited in the flysch trough running northeast - southwest across Northern Iraq. These subzones are not sampled in Kirkuk No. 116 as no samples were available above the *Tribrachiatus orthostylus* Subzone. The sedimentation rate in Pulkhana No. 5 is 2.82 M/ Ma. and in Chemchemal No. 2 the sedimentation rate averages 103.63 M/ Ma. . The sedimentation rate during the deposition of the *Sphenolithus conspicuus* Subzone (IT8c) from 49.6 Ma. to 50.5 Ma. is 23.94 M/ Ma., while the sedimentation rate during the deposition of the *Discoaster kuepperi* Zone (IT8) from 49.0 Ma. to 49.6 Ma. is a minimum of 213.36 M/ Ma., as the top of the zone is not seen in this well section. The sedimentation in Chemchemal No.2 shows a marked increase during this period to a similar level to that during the deposition of the *Discoaster multiradiatus* Zone (IT9). This increase in sedimentation rate may be reflecting the beginning of another period of tectonic activity, causing the high in the northeast rise at a similar rate to that during the deposition of the *Tribrachiatus contortus* A Subzone (IT9b) and *Rhomboaster bitrifida* Subzone (IT9c) in the high to the northeast (see Figure 7.1).

7.1.3 Mid Eocene:

The zones deposited during this time period are the *Reticulofenestra dictyoda* (IT6) Zone and *Reticulofenestra callida* Zone (IT7). These are discussed below in ascending stratigrapnic order, while the subsidence history is graphically shown in Figure 7.2. This Mid Eocene sequence is deposited unconformably upon Early Eocene strata and the hiatus spans approximately 2.3 Ma. . This hiatus was noted in only one well section Pulkhana No. 5. The unconformity may be result of a global sea level fall associated with the late Early Eocene and the early Mid Eocene or as Buday (1980) suggests, the unconformity is associated with the Van Phase of orogenic movement during the Laramide orogeny. Aubry (1991) studied the Early Eocene/ Mid Eocene global sea level fall in a number of sections. She noted two types of unconformity and associated hiatuses around the lower/ middle Eocene boundary:

1. Old hiatuses in the latest early Eocene which are generally short around 1 Ma. .
2. Relatively younger hiatus in the early Mid Eocene have a longer time span of > 2 Ma., as in the case of the study area.

She also noted that unconformities on a shelf may result from a global sea level fall while their stratigraphically correlative unconformites on the slope and rise may result from tectonic instability.

7.1.3(i) *Reticulofenestra callida* Zone (Mid Eocene NP15 / CP13):

This zone occurs in several well sections including Kirkuk No. 85, Pulkhana No. 5 and Rachi No. 1. However it was not possible to determine the sedimentation rate in Rachi No. 1 as the zone is poorly preserved and not fully developed in this well section. The sedimentation rate in Pulkhana No. 5 is 22.23 M/ Ma. which is almost twice the rate at Kirkuk No. 85 which is 11.52 M/ Ma during this time period. The reduced sedimentation rate in Kirkuk No. 85 is probably due to the fact that the full *Reticulofenestra callida* Zone has not been sampled as the well reaches was terminated before the base of the zone was reached and because Kirkuk No. 85 lies on edge of the basin while Pulkhana No. 5 occupies a more central position in the basin.

7.0 Discussion

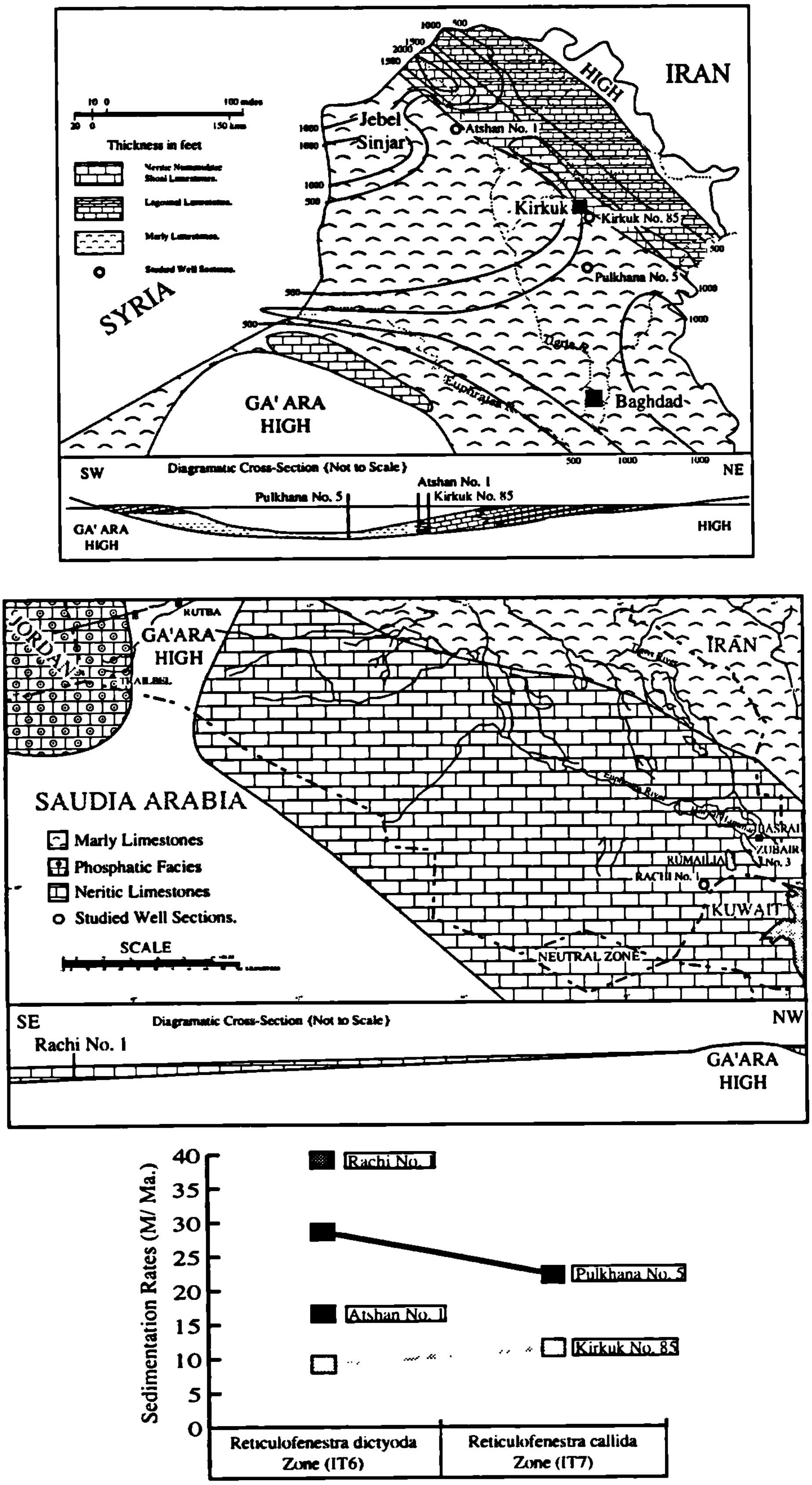


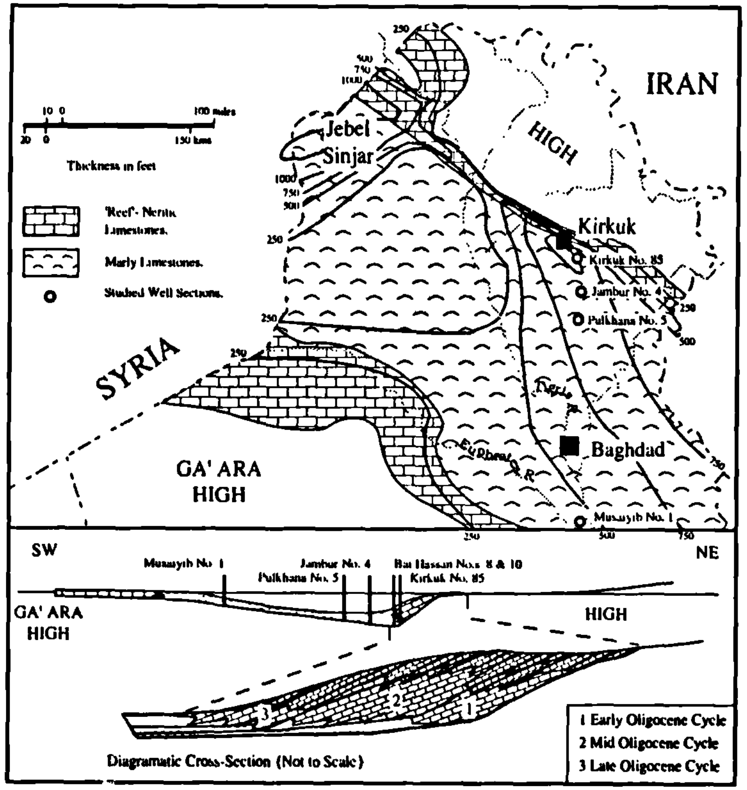
Figure 7.2 Facies Maps, Models and Sedimentation Rate Data for the Mid Eocene of Northern and Southern Iraq (Partly Modified after Dunnington, 1958 and Buday, 1980).

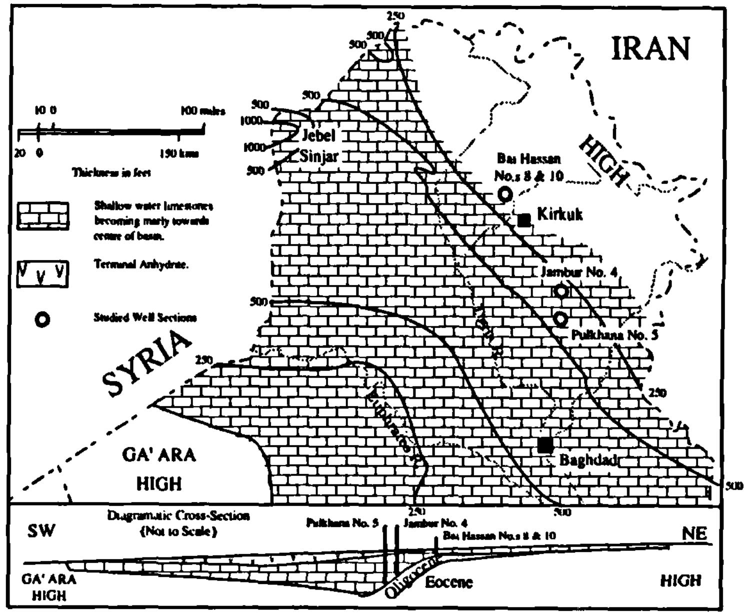
7.1.3 (ii) *Reticulofenestra dictyoda* (Mid Eocene NP16 / CP14):

The Reticulofenestra dictyoda Zone is detected in Atshan No. 1, Kirkuk No. 85, Musaiyib No. 1, Pulkhana No. 5 and Rachi No. 1 well sections. However, the section Musaiyib No. 1 only samples the very top of the Jaddala Formation meaning that the sedimentation rate cannot be determined in this well section. The sedimentation rate is 28.65 M/ Ma. in Pulkhana No. 5, a minimum of 16.63 M/ Ma. in Atshan No. 1 as the top of the zone is not seen, 9.32 M/ Ma. in Kirkuk No. 85 and is 39.19 M/ Ma. in Rachi No. 1. The Pulkhana No. 5 well section continues have sediments being deposited at a similar rate. The Atshan No. 1 well section which occupied a slightly deeper part of the basin than Kirkuk No. 85 during this time period and could therefore build-up a greater thickness of sediment. The *Reticulofenestra dictyoda* Zone in the southern Iraqi well section Rachi No. 1 has the highest sedimentation rate of all, however this zone includes an interval that contains no nannofossils which indicates a short lived oscillation in sea-level probably as a result of the tectonic process during the continued closure of the Tethys ocean. The rest of the Rachi No. 1 well section is devoid of nannofossils which indicates that full marine conditions were only present during this relatively short time period (39.7 Ma. to around 43.2 Ma.). For the remainder of the Palaeocene to Early Eocene, the area has relatively shallow restricted marine conditions, in which bedded anhydrites and dolomitic, recrystallised and nummulitic limestones were widely deposited.

7.1.4 Early Oligocene:

There is only one zone deposited in this time interval and that is the Ericsonia subdisticha Zone (IT5). The subsidence history for this time interval is illustrated in Figure 7.3 for the whole of the Oligocene. This zone is deposited unconformably upon the Mid Eocene sequence and the hiatus spans from 39.7 Ma. - 34.2 Ma. a duration of 5.5 Ma.. This unconformity is probably the result of the initial collision of the Afro-Arabian Plate and the Eurasian plate during the Mid to Late Eocene. Sedimentation was renewed but was restricted to a narrow elongate basin running northwest - southeast to the north of the Ga'ara High. This basin also ran from the Mediterranean through Northern Iraq north of the Ga'ara High into Southwest Iran to





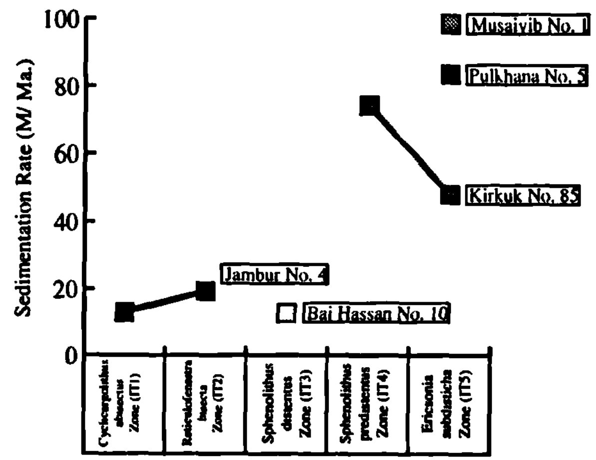


Figure 7.3 Isopach-Facies Maps, Models and Sedimentation Rate Data for the Oligocene to Early Miocene of Northern Iraq (Partly Modified after Dunnington, 1958).

link up with the Indian Ocean. This basin was established by the down-warping of the crust of the Afro-Arabian Plate as it continued to move northwards against the Eurasian Plate (see Chapter Three Tectonics and Structure).

7.1.4(i) *Ericsonia subdisticha* Zone (Early Oligocene NP21 / CP16):

This zone occurs in several well sections including Jambur No. 4, Pulkhana No. 5 and Kirkuk No. 85 and Musaiyib No. 1. However, the sedimentation rate was not calculated for Jambur No. 4 as only the top of the Ericsonia subdisticha Zone has been sampled. The sedimentation rates in the remaining well sections are 83.45 M/ Ma. in Pulkhana No. 5, 98.48 M/ Ma. in Musaiyib No. 1 and 48.06 M/ Ma. in Kirkuk No. 85. The Pulkhana No. 5 well section has a high sedimentation rate as it is situated in a relatively deep part of the basin. This basin has no flysch trough or internal emergent barriers to restrict sediments entering the central parts of the basin. The well section Musaiyib No. 1 has a higher sedimentation rate than Pulkhana No. 5 despite its location in a relatively shallower area of the basin. The higher sedimentation rate in Musaiyib No. 1 is probably as a result of the well section being located close to a sediment source, the Ga'ara High on the southern margin of the basin. In addition the *Ericsonia subdisticha* Zone (IT5) in Pulkhana No. 5 is unconformably overlain by the *Reticulofenestra bisecta* Zone (IT2) which may have reworked part of the underlying zone. The Kirkuk No. 85 well section has a relatively low sedimentation rate compared to the other well sections, as it occupied a relatively high point in the basin at the foot of a reef complex (see Figure 7.3).

7.1.5 Mid Oligocene:

There is only one zone associated with the Mid Oligocene the *Sphenolithus predistentus* Zone (IT4). The subsidence history for the whole of the Oligocene is illustrated in Figure 7.3. This zone is deposited unconformably upon the *Ericsonia subdisticha* Zone (IT5) in Kirkuk No. 85. The unconformity is very short perhaps spanning a maximum of 0.5 Ma. . It is difficult to assess whether the base of NP22/ CP16c has been reached as the zone is poorly preserved when it occurs. This unconformity is probably the result of a short term fluctuation in sea-level during the

Mid Oligocene.

7.1.5(i) *Sphenolithus predistentus* Zone (Mid Oligocene NP22 / CP16c):

This zone occurs in Bai Hassan No. 8 and Kirkuk No. 85 however, the zone is poorly defined in Bai Hassan No. 8 and so the sedimentation rate was not established in this well section. The sedimentation rate in Kirkuk No. 85 is 74.31 M/ Ma. but this is a minimum sedimentation rate as the top of the zone was not recognised due to poor preservation. The sedimentation rate during the Mid Oligocene in Kirkuk No. 85 is relatively high compared with the location the well section occupies, which is a relatively high position in the basin at the foot of a reef complex. This is most likely due to inaccuracies caused due to the poorly preserved nature of the *Sphenolithus predistentus* Zone (see Figure 7.3).

7.1.6 Late Oligocene to Early Miocene:

The zones associated with this time interval are the *Sphenolithus distentus* Zone (IT3), *Reticulofenestra bisecta* Zone (IT2) and the *Cyclicargolithus abisectus* Zone (IT1). The subsidence history for this time interval is illustrated in Figures 7.3. Though a minor unconformity between the Mid and Late Oligocene is chronicled by van Bellen *et al.* (1959), it was not confirmed by this study. The *Reticulofenestra bisecta* Zone is recognised in the Serikagni Formation and the *Sphenolithus distentus* Zone was recognised in the Ibrahim Formation. Van Bellen *et al.* (1959) chronicles an unconformity between these two formations but this was not observed during this study due to the lack of relevant sample material.

7.1.6 (i) *Sphenolithus distentus* Zone (Late Oligocene NP24 / CP19b):

The *Sphenolithus distentus* Zone (IT3) was only recorded in the Bai Hassan No. 10 well section during this study. The sedimentation rate is 12.62 M/ Ma. but, this is a minimum value as the base of the zone had not been reached before the well was terminated. The moderate sedimentation rate is associated with the location of the well at the foot of a reef complex.

7.1.6(ii) *Reticulofenestra bisecta* Zone (Latest Oligocene to Early Miocene NP25 - NN1/ CP19b - CN1a):

The *Reticulofenestra bisecta* Zone (IT2) is present in Pulkhana No. 5 and Jambur No. 4. The sedimentation rate was not calculated for Pulkhana No. 5 as only the base of the zone was sampled. The sedimentation rate during the deposition of this zone in Jambur No. 4 is approximately 19.18 M/ Ma., this figure is a minimum rate as it is likely that only the top of NP25 is represented in this well section. The moderate sedimentation rate is associated with the location of the well at the foot of a reef complex.

7.1.6(iii) *Cyclicargolithus abisectus* Zone (Early Miocene NN1 / CN1a):

The *Cyclicargolithus abisectus* Zone occurs only in Jambur No. 4. The sedimentation rate during the deposition of this zone is 12.84 M/ Ma.. The sedimentation rate is related to the location of the well at the foot of a reef complex. During the deposition of this zone the rate of sedimentation was increased in relation to the previous two zones. This may be due to increased amount of erosion on the rising high towards the northeast and reef complex, associated with the tectonics events caused by the continued closure of the Tethys ocean.

7.2 Biogeography:

7.2.1 Introduction:

The theory that certain calcareous nannofossil groups indicate less than normal marine conditions than others is not new. The idea first gained appeal following the advent of deep ocean drilling, when it was noted that many distinct, ornate species previously described from outcrop sections were rare or absent in deep ocean sediments. Bukry (1970) was the first to notice this phenomena in Early Oligocene sediments from the western North Atlantic. He also noted the phenomena in sediments he used to establish the Okada and Bukry (1980) zonation scheme for low latitudes (see Figure 6.13), as the top of the *Chiasmolithus bidens* Zone was marked by the first occurrence of *Campylosphaera eodela* in deep water and *Rhomboaster* spp. in shallow water. However the depth of water as a controlling factor on the provinciality of calcareous nannofossils is unlikely as the nannofossils in life occupied the top 100 metres of the water column, the photic zone. Gartner (1977) also noted the phenomena and pointed out that the two most widely used global nannofossil zonation schemes Martini (1971) and Bukry (1973, 1975), which formed the basis for the later Okada and Bukry (1980) low latitude scheme, are based at least in part on hemipelagic marker species rather than more cosmopolitan forms, thus restricting their usage in the deep ocean sediments. Gartner (1977) also noted another important consideration that a certain calcareous nannofossil group may of inhabited restricted hemipelagic environments during certain periods and then later may have evolved into more cosmopolitan forms. Though a great deal of work has been carried out on Miocene and younger calcareous nannofossil assemblages very little work has been done on more ancient sediments. This is probably due to the lack of understanding of the biological tolerances of the more ancient forms as using more recent calcareous nannofossil analogues to understand extinct forms is not always be valid as Gartner (1977) illustrated with the changing environmental tolerances of the Helicosphaeraceae. The Helicosphaeraceae appear as hemipelagic forms in the Early Eocene and then by the Mid Miocene it becomes more or less cosmopolitan, suggesting that they have changed their environmental preference or tolerance during this time period. Therefore detailed work on well known environments are required to produce abundance figures and listings for both ancient and modern nannofossil assemblages so that the environmental tolerances of the different nannofossil groups can be established. This work then can be used as a standard for areas where the environment is not fully understood.

For this present study, several of the well sections sampled the Mid Palaeocene to Early Eocene, the Mid Eocene and the Early Oligocene sequences, in which the depositional environment and palaeogeography is well established. During the establishment of the calcareous nannofossil biostratigraphy for the study area it noted that certain groups of nannofossils occur in greater numbers or exclusively certain areas, while others nannofossil groups occur over the whole area, and therefore it seemed that an ideal opportunity was available to try and attempt to understand the environmental controls effecting the distribution of the nannofossil assemblages. However, this study is limited as the samples used tend to be mainly drill cuttings which suffer from the effects of caving. In addition, the nannofossil assemblages tend to be moderately overgrown with secondary calcite and the number of well sections available for this work during this study is low. Despite these disadvantages some useful information on the nannofossil assemblages was obtained. The analysis is based upon the diversity of calcareous nannofossils within a family and the average percentage of the total nannofossil assemblage that family makes up, within a particular well section during a particular zone. This information is presented below under there respective time intervals with some preliminary interpretations.

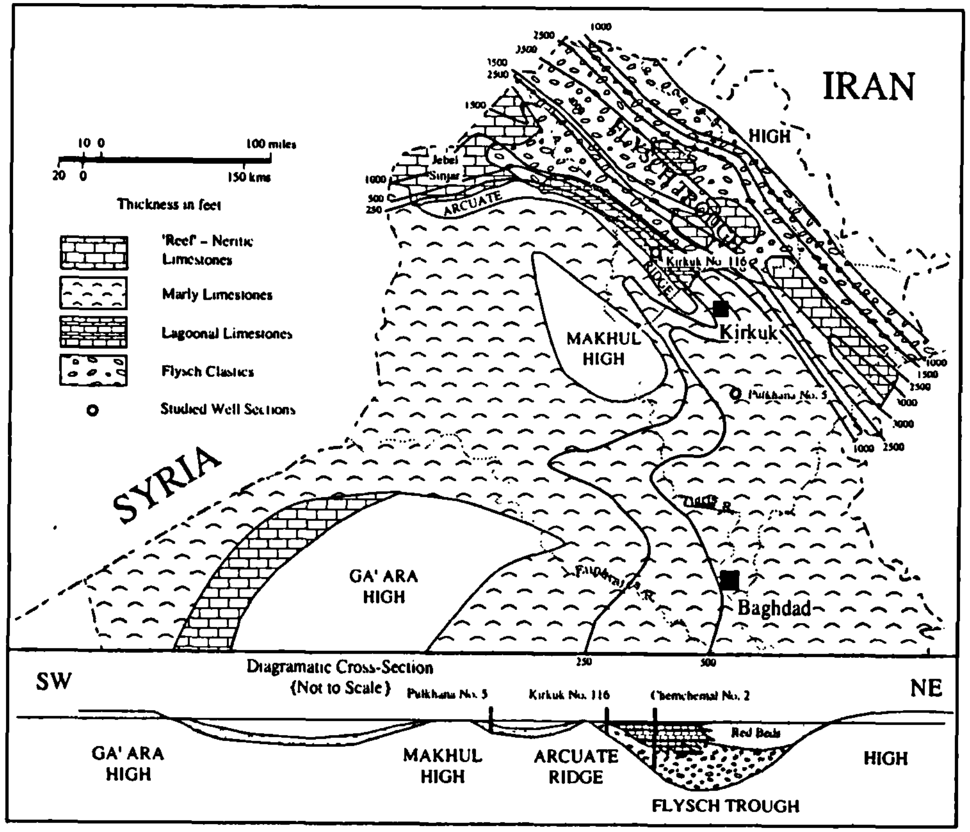
7.2.2 Mid Palaeocene to Early Eocene:

During this time interval 5 zones and 7 subzones have been established based upon three well sections Pulkhana No. 5, Kirkuk No. 116 and Chemchemal No. 2, but however not all of these zones and subzones can be recognised in all of the well sections and therefore zones have been grouped to make analysis possible. The calcareous nannofossil assemblages associated with these grouped zones are discussed below:

7.2.2(i) Fasciculithus pileatus Zone (IT12):

The main features of the calcareous nannofossil assemblages noted in the well sections containing the *Fasciculithus pileatus* Zone (IT12) are illustrated in Figure 7.4 and discussed below in detail. It should be noted that only two well sections contain this zone in the study area Kirkuk No. 116 and Pulkhana No. 5, and in the later well section the zone is poorly preserved.

- Coccolithaceae and Noelaerhabdaceae are cosmopolitan being found in both well sections.
- Zygodiscaceae increase in abundance and diversity, Fasciculithaceae increases in diversity and *Thoracosphaera operculata* increases in abundance towards the high in the northeast, in the Kirkuk No. 116 well section.



Fasciculithus pileatus Zone (IT12).		
Calcareous Nannofossil Assemblage	Kirkuk No. 116	Pulkhana No. 5
Coccolithaceae	40.36%	6.87%
Chiasmolithus bidens	✓	X
Cruciplacolithus tenuis	✓	X
Coccolithus pelagicus	✓	✓
Ericsonia robusta	✓	✓
Markalius inversus	X	✓
Noelaerhabdaceae	47.93%	36.01%
Prinsius bisulcus	✓	✓
Prinsius martinii	✓	X
Toweius eminens	✓	✓
Toweius tovae	✓	✓
Sphenolithaceae	2.69%	2.66%
Sphenolithus anarrhopus	X	✓
Sphenolithus moriformis Group	✓	✓
Thoracosphaeraceae	2.69%	2.66%
Thoracosphaera operculata	✓	✓
Zygodiscaceae	2.69%	0.32%
Neochiastozygus modestus	✓	✓
Zygodiscus bramlettei	✓	X
Fasciculithaceae	1.35%	5.96%
Fasciculithus bitectus	✓	X
Fasciculithus janii	✓	X
Fasciculithus pileatus	✓	✓
Fasciculithus schaubii	X	✓
Fasciculithus tympaniformis	✓	✓

✓ Present
X Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.4 Isopach-Facies Map, Model and Calcareous Nannofossil Assemblage Data for the Mid Palaeocene of Northern Iraq (Partly Modified after Dunnington, 1958).

- Sphenolithaceae increases in abundance towards the basin centre in Pulkhana No. 5.

7.2.2(ii) Heliolithus kleinpellii Zone (IT11):

The main features of the calcareous nannofossil assemblages noted in the well sections containing the *Heliolithus kleinpellii* Zone (IT11) are illustrated in Figure 7.5 and are essentially the same as that in the *Fasciculithus pileatus* Zone (IT12) with the addition of:

- Heliolithaceae is fairly cosmopolitan but shows a slight increase in abundance towards the centre of the basin in Pulkhana No. 5.
- Discoasteraceae, Braarudosphaeraceae, Incertae Sedis and *Scapholithus rhombiformis* seem to show an increase in abundance and diversity towards the high in the northeast.

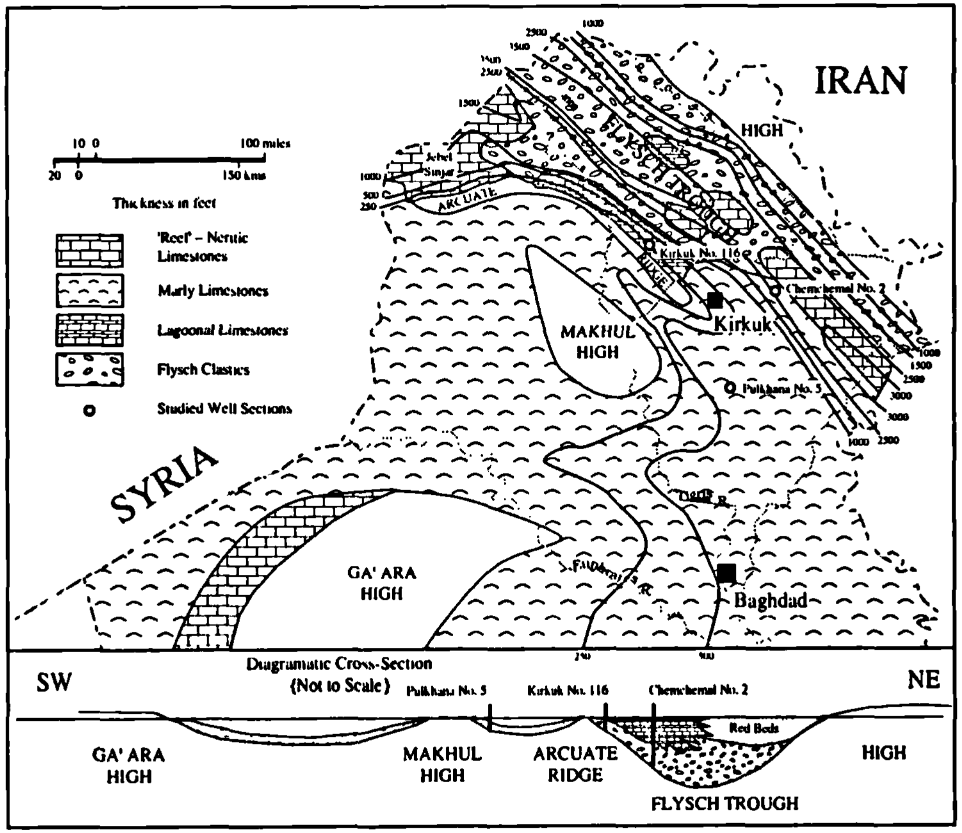
7.2.2(iii) Fasciculithus tympaniformis Zone (IT10):

The main features of the calcareous nannofossil assemblages noted in the well sections containing the *Fasciculithus tympaniformis* Zone (IT10) are illustrated in Figure 7.6 and are essentially the same as the *Heliolithus kleinpellii* Zone (IT11) with the most notable differences being:

- Fasciculithaceae shows a large increase in both abundance and diversity towards the high in the northeast, which allows the *Fasciculithus hayi* Subzone (IT10a) to be recognised in the Kirkuk No. 116 and Chemchemal No. 2 well sections.
- *Scapholithus rhombiformis* seems to exhibit a more cosmopolitan occurrence in this zone.

7.2.2(iv) Discoaster multiradiatus/ Discoaster kuepperi (IT9 and IT8):

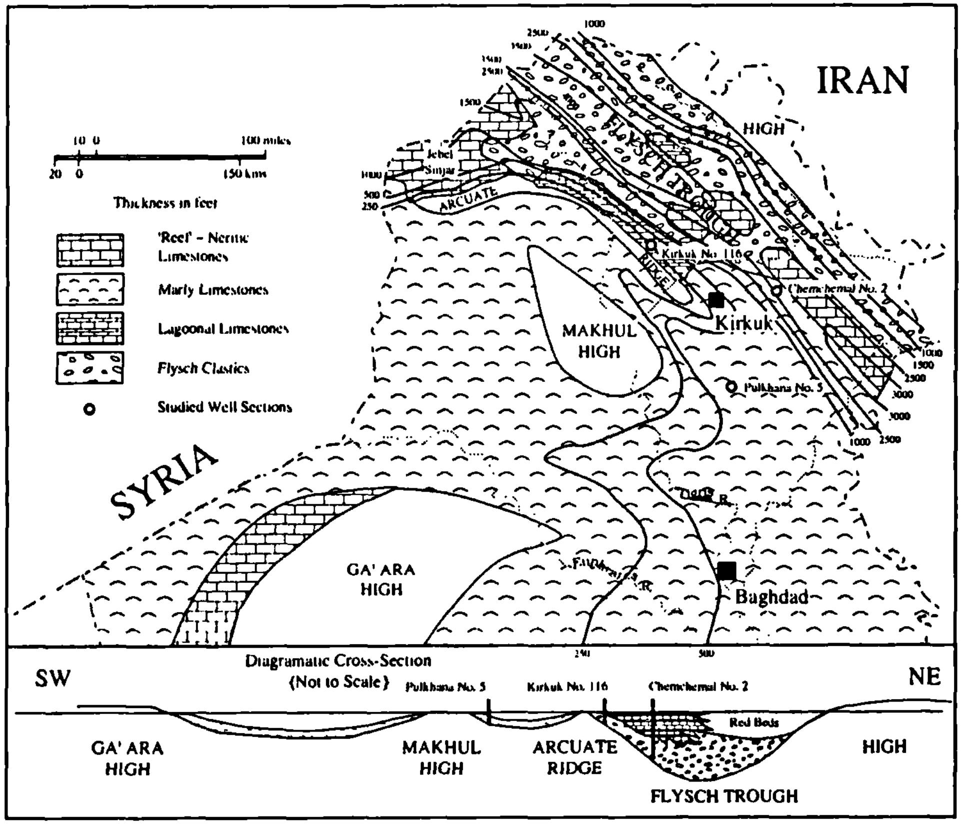
The main features of the nannofossil assemblages noted in the well sections containing the *Discoaster multiradiatus/ Discoaster kuepperi* Zones (IT9 and IT8) are illustrated



Heliolithus kleinpellii Zone (IT11).			
Calcareous Nannofossil Assemblage	Chemchemal No. 2	Kirkuk No. 116	Pulkhana No. 5
Coccolithaceae	34.43%	31.11%	25.63%
Campylosphaera eodela	✓	X	X
Chiasmolithus bidens	X	✓	X
Chiasmolithus consuetus	✓	X	X
Coccolithus pelagicus	✓	✓	✓
Ericsonia robusta	✓	✓	✓
Markalius inversus	X	✓	✓
Noelaerhabdaceae	51.3%	47.93%	36.01%
Prinsius bisulcus	✓	✓	✓
Prinsius dimorphosus	✓	X	X
Prinsius martinii	✓	✓	✓
Toweius eminens	✓	✓	X
Toweius pertusus	✓	X	X
Toweius tovae	✓	✓	✓
Discoasteraceae	0.48%	1.55%	–
Discoaster mohleri	X	✓	X
Discoaster multiradiatus	✓	✓	X
Sphenolithaceae	3.40%	3.09%	17.42%
Sphenolithus anarrhopus	✓	✓	✓
Sphenolithus moriformis Group	✓	✓	✓
Braarudosphaeraceae	0.40%	0.32%	–
Braarudosphaera bigelowii	✓	✓	X
Thoracosphaeraceae	8.40%	1.84%	1.45%
Thoracosphaera operculata	✓	✓	✓
Zygodiscaceae	0.50%	–	0.67%
Neochiastozygus denticulata	✓	X	X
Neochiastozygus distentus	✓	X	X
Neochiastozygus junctus	✓	X	X
Neochiastozygus perfectus	✓	X	X
Neococcolithes protenus	✓	X	X
Placozygus sigmoides	✓	X	✓
Fasciculithaceae	5.1%	8.85%	9.21%
Fasciculithus alanii	✓	X	X
Fasciculithus schaubii	✓	X	X
Fasciculithus thomasii	✓	X	X
Fasciculithus tympaniformis	✓	✓	✓
Calciosoleniaceae	0.56%	0.33%	–
Scapholithus rhombiformis	✓	✓	X
Heliolithaceae	0.83%	1.11%	2.35%
Heliolithus kleinpellii	✓	✓	✓
Incertae Sedis	2,32%	2.00%	0.34%
Ellipsolithus distichus	X	✓	X
Ellipsolithus macellus	✓	✓	✓

✓ Present
X Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.5 Isopach-Facies Map, Model and Calcareous Nannofossil Assemblage Data for the Mid to Late Palaeocene of Northern Iraq (Partly Modified after Dunnington, 1958).



Fasciculithus tympaniformis Zone (IT10).			
Calcareous Nannofossil Assemblage	Chemchemal No 2	Kirkuk No 116	Pulkhana No 5
Coccolithaceae	31.25%	34.65%	16.74%
Campylosphaera eodela	✓	✓	✗
Chiasmolithus bidens	✗	✓	✗
Chiasmolithus consuetus	✓	✓	✗
Coccolithus pelagicus	✓	✓	✓
Ericsonia robusta	✓	✓	✓
Markalius inversus	✓	✓	✗
Noelaerhabdaceae	38.55%	37.43%	26.87%
Prinsius bisulcus	✓	✓	✓
Prinsius martinii	✓	✓	✓
Toweius eminens	✓	✓	✓
Toweius tovae	✓	✓	✓
Discoasteraceae	9.86%	2.31%	–
Discoaster b. binodosus	✓	✗	✗
Discoaster mohleri	✓	✓	✗
Discoaster multiradiatus	✓	✓	✗
Discoaster nobilis	✗	✓	✗
Discoaster salisburgensis	✓	✗	✗
Sphenolithaceae	8.51%	3.51%	43.70%
Sphenolithus anarrhopus	✓	✓	✓
Sphenolithus moriformis Group	✓	✓	✓
Pontosphaeraceae	1.16%	–	–
Pontosphaera spp.	✓	✗	✗
Braarudosphaeraceae	0.40%	0.32%	–
Braarudosphaera bigelowii	✓	✓	✗
Thoracosphaeraceae	8.40%	1.84%	1.45%
Thoracosphaera operculata	✓	✓	✓
Zygodiscaceae	2.54%	1.73%	0.91%
Lophodolithus nascens	✓	✓	✗
Neochiastozygus distentus	✓	✓	✓
Neochiastozygus junctus	✓	✓	✗
Neococcolithes protenus	✓	✗	✗
Placozygus sigmoides	✓	✓	✗
Zygodiscus bramlettei	✓	✓	✗
Fasciculithaceae	12.6%	13.81%	3.61%
Fasciculithus alanii	✓	✓	✗
Fasciculithus bobii	✓	✗	✗
Fasciculithus hayi	✓	✓	✗
Fasciculithus involutus	✓	✓	✗
Fasciculithus richardii	✓	✗	✗
Fasciculithus thomasii	✓	✓	✗
Fasciculithus tympaniformis	✓	✓	✓
Fasciculithus sp. 1	✓	✗	✗
Calciosoleniaceae	0.96%	0.80%	1.09%
Scapholithus rhombiformis	✓	✓	✓
Incertae Sedis	0.96%	0.69%	2.17%
Ellipsolithus distichus	✓	✗	✓
Ellipsolithus macellus	✓	✓	✓
Rhomboaster bitrifida	✓	✗	✗

✓ Present
✗ Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.6 Isopach-Facies Map, Model and Calcareous Nannofossil Assemblage Data for the Late Palaeocene to Early Eocene of Northern Iraq (Partly Modified after Dunnington, 1958).

in Figure 7.7 and are discussed in detail below:

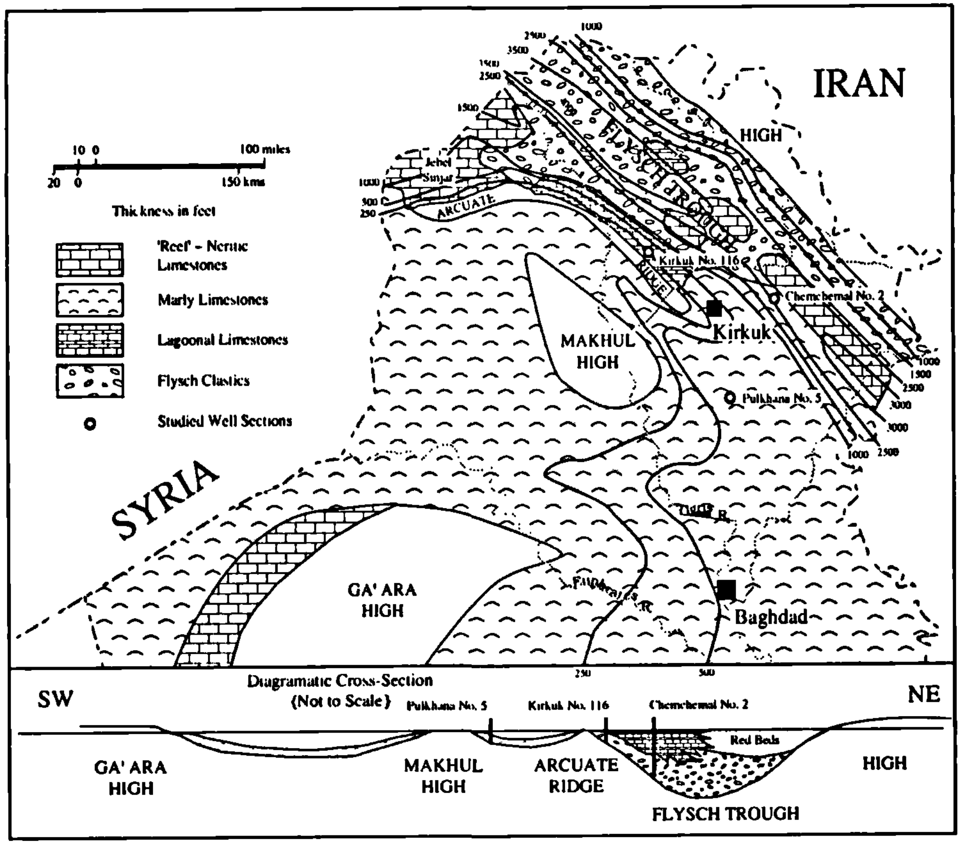
- Coccolithaceae and Noelaerhabdaceae are cosmopolitan being recorded in similar numbers and abundance in all well sections.
- Sphenolithaceae and Discoasteraceae increases in abundance towards the basin however diversity increases towards the high towards the northeast. This increase in diversity allows the zones to be split further in the near shore well section.
- Pontosphaeraceae, Braarudosphaeraceae, Zygodiscaceae, Rhabdolithaceae, Incertae sedis, *Zygrhablithus bijugatus* and *Thoracosphaera operculata* tend to increase in abundance and diversity towards the high in the northeast. This increase in diversity again allows the zones to be split further in the near shore well sections.

The reasons for the increase in abundance and diversity in certain calcareous nannofossil groups particularly associated with the high in the northeast of Iraq during the Mid Palaeocene to Early Eocene period are listed below. However, it is also interesting to note that similar calcareous nannofossil assemblages were noted by Perch-Nielsen *et al.* (1974) in Egypt, and when the palaeogeography is taken into consideration, the outcrop sections studied by them are situated close to the Arabo-Nubian massif. The possible explanations for the concentration of certain calcareous nannofossil groups in the study area are:

(1). The fact the sampled sections are more condensed in the basinward well section Pulkhana No. 5 and therefore the sampling interval chosen may of just missed these abundance and diversity events.

(2). The waters were probably more sediment charged towards Chemchemal No. 2 as this well section occupied a flysch trough during this time interval. These environmental conditions may therefore have restricted the occurrence and abundance of certain nannofossil groups.

(3). The concentration of certain nannofossil groups towards the high in the northeast may of been a response to the decrease in salinity caused by the addition of freshwater as a result of runoff from the erosion of high. There is



Discoaster kuepperi Zone(IT8)/ Discoaster multiradiatus Zone(IT9)			
Calcareous Nannofossil Assemblage	Chemchemal No. 2	Kirkuk No. 116	Pulkhana No. 5
Coccolithaceae	32.97%	28.55%	25.90%
Campylosphaera eodela	✓	✓	✓
Chiasmolithus bidens	✓	✓	✓
Chiasmolithus consuetus	✓	✓	✓
Coccolithus pelagicus	✓	✓	✓
Ericsonia formosa	✓	✓	✓
Ericsonia obrupta	✓	✓	✓
Ericsonia robusta	✓	✓	X
Markalius inversus	✓	✓	✓
Noelaerhabdaceae	22.64%	10.32%	0.95%
Reticulofenestra dictyoda	X	✓	✓
Prinsius bisulcus	✓	✓	X
Toweius eminens	✓	✓	X
Toweius pertusus	✓	✓	X
Discoasteraceae	2.69%	10.32%	14.79%
Discoaster barbadiensis	✓	✓	✓
Discoaster b. binodosus	✓	X	X
Discoaster deflandrei	✓	✓	✓
Discoaster falcatus	✓	X	X
Discoaster kuepperi	✓	✓	✓
Discoaster lodoensis	✓	✓	✓
Discoaster mohleri	X	X	✓
Discoaster multiradiatus	✓	✓	X
Discoaster saipanensis	X	X	✓
Discoaster salisburgensis	✓	✓	X
Discoaster cf. *D. stella*	✓	X	X
Sphenolithaceae	25.76%	23.41%	43.77%
Sphenolithus conspicuus	✓	X	X
Sphenolithus editus	✓	✓	X
Sphenolithus elongatus	✓	X	X
Sphenolithus furcatolithoides	✓	X	X
Sphenolithus moriformis Group	✓	✓	✓
Sphenolithus radians	✓	✓	✓
Pontosphaeraceae	2.41%	2.16%	0.32%
Pontosphaera spp.	✓	✓	X
Transversopontis pulcher	✓	✓	✓
Braarudosphaeraceae	2.30%	0.89%	4.61%
Braarudosphaera bigelowii	✓	✓	✓
Micrantholithus flos	✓	✓	✓
Micrantholithus pinguis	✓	X	X
Rhabdosphaeraceae	0.66%	–	–
Rhabdolithus solus	✓	X	X
Calyptrosphaeraceae	8.31%	3.06%	8.05%
Zygrhablithus bijugatus	✓	✓	✓
Thoracosphaeraceae	3.25%	2.06%	–
Thoracosphaera operculata	✓	✓	X
Zygodiscaceae	1.66%	2.41%	–
Lophodolithus nascens	✓	X	X
Neochiastozygus distentus	✓	✓	X
Neochiastozygus junctus	✓	✓	X
Neococcolithes protenus	✓	X	X
Incertae Sedis	1.77%	1.34%	0.80%
Ellipsolithus macellus	✓	X	X
Rhomboaster bitrifida	✓	X	X
Tribrachiatus orthostylus A	✓	✓	X
Tribrachiatus orthostylus B	✓	✓	✓
Tribrachiatus contortus A	✓	X	X

✓ Present
X Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.7 Isopach-Facies Map, Model and Calcareous Nannofossil Assemblage Data for the Early Eocene of Northern Iraq (Partly Modified after Dunnington, 1958).

some evidence for reduced salinity conditions in this area as Majiid and Vieser (1986) noted that the limestones in this area were deposited in waters with a salinity between that of freshwater and seawater. In addition the concentration of the Braarudosphaeraceae towards the high in the northeast ~~may also~~ reflect salinity, as increased occurrences of the family has been linked to hyposaline conditions in the Mid Miocene of Israel by Moshkovitz and Ehrlich (1981). However, it must also be pointed out that large numbers of Braarudosphaeraceae are also associated with deep ocean sediments at the Cretaceous/ Tertiary boundary and are thought to reflect unstable water masses at this time.

(4). Haq and Aubry (1980) noted that *Prinsius martini* continued to occur until the end of the Late Palaeocene in all the outcrop and well sections they studied in the Middle East (see Chapter Six Biostratigraphy, 6.4.1 (ii) Regional Calcareous Nannofossil Zonation Schemes). Haq and Aubry took this continued occurrence to indicate the influence of a cold water mass during this time period. This same event was noted in this present study in all of the well sections and so may indicate the same occurrence of a cold water mass.

(5) The abundance and diversity of discoasters within the *Discoaster multiradiatus/ Discoaster kuepperi* Zones (IT9 and IT8) and particularly the occurrence of *D. barbadiensis* and *D. saipanensis* may be linked to warm surface environments (Bukry 1971b).

It is difficult to assess which of these explanations is true, however it is probably the combined effect of water mass temperature and decreased salinities in near shore areas, as independent evidence suggests both of these to be active during this time period. Bown *et al.* (1991, 1992) suggested that global warming and cooling was the major influence on Palaeocene to Recent nannofossil assemblages, based upon evolutionary rates and diversity studies. They explained their results by relating them to driving mechanisms such as climate, palaeocenography, nutrient availability, and environmental stability, which in turn was related to the Icehouse-Greenhouse cycles of Fischer (1982). During the Palaeocene to Recent they noted that increased evolutionary variability was related to global cooling as "icehouse" conditions became established. However this general cooling phase was punctuated with several warming and cooling events which led to increases in diversity during warming events and decreases in diversity during cooling events. One of the warming events occurred in the Late Palaeocene and may reflected in the study area by the increased diversity noted in Discoasteraceae, Fasciculithaceae and Zygodiscaceae.

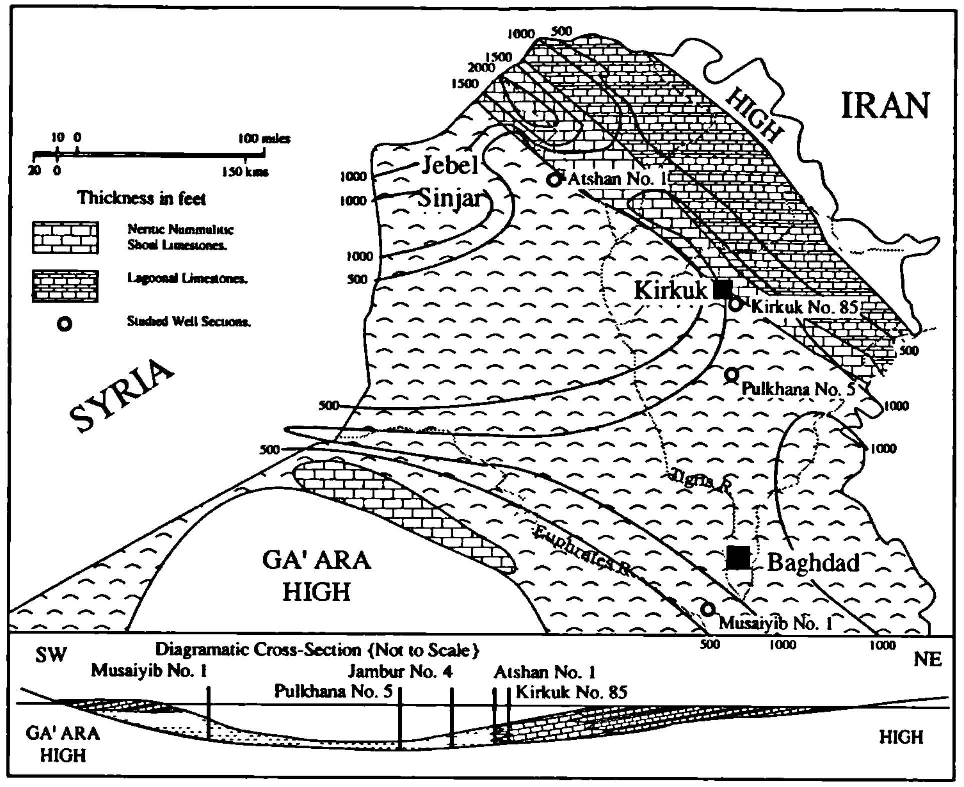
7.2.3 Mid Eocene:

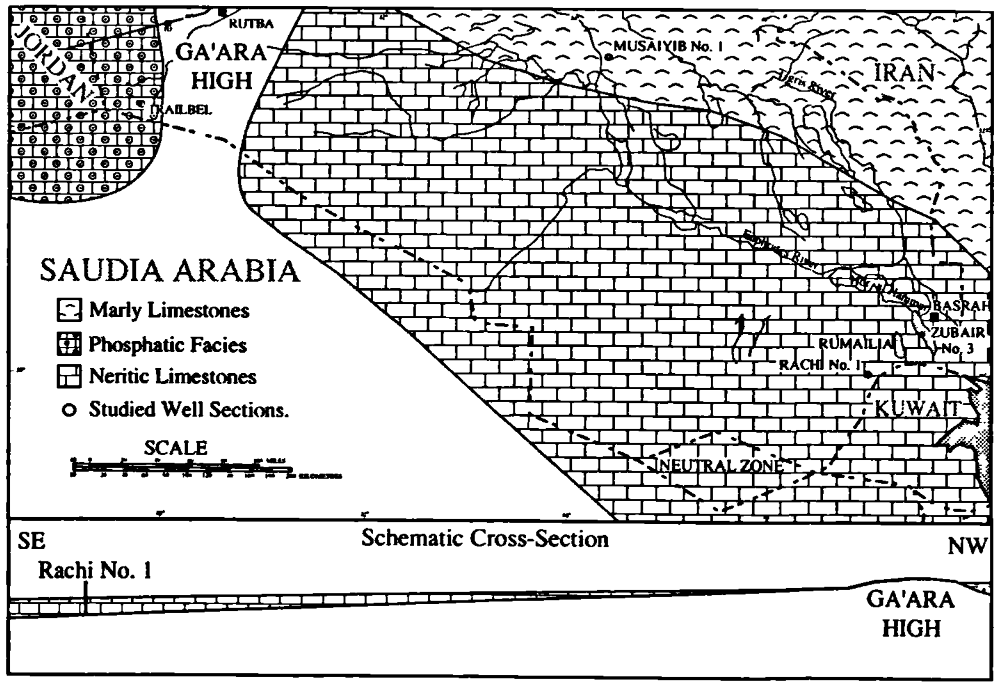
Two zones were noted during this time period and are discussed below and the assemblage characteristics of each zone can be seen in Figures 7.8.

7.2.3(i) Reticulofenestra callida Zone (IT7):

The main features of the nannofossil assemblages noted in the well sections containing the *Reticulofenestra callida* Zone (IT7) are illustrated in Figure 7.8 and is discussed in detail below.

- Coccolithaceae, Noelaerhabdaceae and *Nannotetrina fulgens* all seem to be cosmopolitan in nature though *Nannotetrina fulgens* is absent in Rachi No.1 probably due to the fact that the zone is poorly developed in this well section.
- Discoasteraceae, Pontosphaeraceae, Braarudosphaeraceae and *Zygrhablithus bijugatus* increase in abundance towards the marginal areas of the basin in the Kirkuk No. 85 and Rachi No. 1 well sections.
- Sphenolithaceae seems to exhibit a cosmopolitan nature when the abundance of the family is analysed however, the more familiar pattern of Sphenolithaceae predominating in central areas of the basin appears when the diversity in Pulkhana No. 5 is taken into account.
- Rhabdolithaceae does not exhibit the usual pattern of increase towards marginal areas of the basin as it is concentrated in Pulkhana No. 5 this concentration may be the result of reworking as rhabdoliths are fairly resistant to the effects of reworking.





Reticulofenestra dictyoda Zone (IT6).					
Calcareous Nannofossil Assemblage	Kirkuk No. 85	Atshan No. 1	Pulkhana No. 5	Musaiyib No. 1	Rachi No. 1
Coccolithaceae	23.46%	12.65%	18.87%	17.49%	8.51%
Chiasmolithus bidens	×	✓	×	×	×
Chiasmolithus consuetus	×	×	×	×	✓
Chiasmolithus grandis	×	×	×	×	✓
Chiasmolithus solitus	×	×	×	×	✓
Chiasmolithus titus	×	×	×	×	✓
Coccolithus pelagicus	✓	✓	✓	✓	✓
Ericsonia formosa	✓	✓	✓	✓	✓
Ericsonia obrupta	✓	✓	✓	✓	✓
Markalius inversus	×	×	✓	×	✓
Noelaerhabdaceae	53.80%	68.05%	55.05%	76.24%	67.98%
Cyclicargolithus floridanus	✓	✓	✓	✓	✓
Reticulofenestra bisecta	✓	✓	✓	✓	✓
Reticulofenestra minuta	✓	✓	✓	✓	✓
Reticulofenestra scrippsae	✓	✓	✓	✓	✓
Reticulofenestra umbilica	✓	✓	✓	✓	✓
Helicosphaeraceae	1.55%	—	2.65%	0.33%	1.22%
Helicosphaera compacta	✓	×	✓	✓	×
Helicosphaera euphratis	✓	×	×	✓	✓
Helicosphaera seminulum	×	×	×	×	✓
Discoasteraceae	1.63%	1.47%	0.77%	0.32%	1.11%
Discoaster barbadiensis	✓	✓	×	×	✓
Discoaster gemmeus	×	×	×	×	✓
Discoaster tanii	×	×	×	✓	✓
Discoaster tanii nodifer	✓	×	✓	×	×
Discoaster wemmelensis	×	×	×	×	✓
Sphenolithaceae	10.50%	13.43%	16.21%	2.64%	5.80%
Sphenolithus moriformis Group	✓	✓	✓	✓	✓
Sphenolithus predistentus	✓	×	✓	✓	×
Sphenolithus radians	✓	×	✓	×	✓
Pontosphaeraceae	0.77%	—	0.51%	0.33%	2.63%
Pontosphaera spp.	✓	×	✓	✓	✓
Traversopontis obliquipons	✓	×	×	×	✓
Traversopontis rectipons	×	×	×	×	✓
Braarudosphaeraceae	0.43%	—	0.83%	—	2.21%
Braarudosphaera bigelowii	✓	×	✓	×	✓
Micrantholithus flos	×	×	✓	×	×
Rhabdosphaeraceae	1.14%	—	2.15%	0.33%	1.15%
Rhabdolithus spp.	✓	×	✓	✓	
Calyptrosphaeraceae	6.57%	—	2.9%	6.93%	0.82%
Zygrhablithus bigugatus	✓	×	✓	✓	✓

Reticulofenestra callida Zone (IT7).			
Calcareous Nannofossil Assemblage	Kirkuk No. 85	Pulkhana No. 5	Rachi No. 1
Coccolithaceae	17.39%	19.34%	16.67%
Birkelundia staurion	×	×	✓
Chiasmolithus bidens	×	✓	×
Chiasmolithus consuetus	×	✓	×
Chiasmolithus grandis	×	✓	×
Coccolithus pelagicus	✓	✓	✓
Ericsonia formosa	✓	✓	✓
Ericsonia obrupta	✓	✓	✓
Markalius inversus	×	✓	×
Noelaerhabdaceae	60.05%	59.97%	75.84%
Cyclicargolithus floridanus	✓	✓	✓
Reticulofenestra bisecta	✓	✓	✓
Reticulofenestra callida	✓	✓	✓
Reticulofenestra scrippsae	✓	✓	✓
Reticulofenestra umbilica	✓	✓	✓
Discoasteraceae	2.01%	1.63%	—
Discoaster barbadiensis	×	✓	×
Discoaster saipanensis	×	✓	×
Discoaster tanii	×	✓	×
Discoaster tanii nodifer	✓	✓	×
Sphenolithaceae	9.72%	9.40%	5.00%
Sphenolithus furcatolithoides	×	✓	×
Sphenolithus moriformis Group	✓	✓	✓
Sphenolithus predistentus	✓	✓	×
Sphenolithus radians	✓	✓	×
Sphenolithus spiniger	×	✓	×
Pontosphaeraceae	0.75%	0.49%	—
Pontosphaera spp.	✓	✓	×
Braarudosphaeraceae	0.65%	—	—
Braarudosphaera bigelowii	✓	×	×
Rhabdosphaeraceae	0.86%	2.12%	—
Rhabdolithus spp.	✓	✓	×
Calyptrosphaeraceae	6.87%	2.93%	2.50%
Zygrhablithus bigugatus	✓	✓	✓
Incertae Sedis	0.65%	0.75%	—
Nannotetrina fulgens	✓	✓	×

✓ Present
× Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.8 Facies Maps and Calcareous Nannofossil Assemblage Data for the Mid-Late Eocene of Northern and Southern Iraq (Partly Modified after Dunnington, 1958 and Buday, 1980).

7.2.3(ii) Reticulofenestra dictyoda Zone (IT6):

The main features of the calcareous nannofossil assemblages noted in the well sections containing the *Reticulofenestra dictyoda* Zone (IT6) are illustrated in Figure 7.8 and is discussed in detail below.

- Coccolithaceae and Noelaerhabdaceae are cosmopolitan in nature through out all the well sections containing this zone, though in Rachi No. 1 the family Coccolithaceae is less abundant than elsewhere and conversely the genus *Chiasmolithus* is particularly diverse in this well section.
- Helicosphaeraceae is fairly cosmopolitan during this time interval however the family does show an increase in diversity towards the more marginal areas of the basin in Kirkuk No. 85, Musaiyib No. 1 and Rachi No. 1 well sections.
- Discoasteraceae during this time period shows an increase in abundance towards the marginal areas of the basin in the Atshan No. 1, Kirkuk No. 85, Musaiyib No. 1 and Rachi No. 1 and shows a particular increase in diversity toward the south in Rachi No. 1.
- Sphenolithaceae again shows an increase in abundance towards the centre of the basin in the Pulkhana No. 5 well section.
- Pontosphaeraceae and Braarudosphaeraceae increase in both abundance and diversity in the more marginal areas of the basin in the Kirkuk No. 85, Musaiyib No. 1 and Rachi No. 1, this is particularly evident in Rachi No. 1.
- Rhabdolithaceae and *Zygrhablithus bijugatus* generally increase in abundance towards the marginal areas of the basin but, in Pulkhana No. 5 particularly high numbers of Rhabdolithaceae occur probably as a result of reworking since rhabdoliths are fairly resistant to the effects of reworking. In addition *Zygrhablithus bijugatus* is not very abundant in Rachi No. 1 which may be due to a difference in the environmental conditions as *Zygrhablithus bijugatus* is abundant in the other marginal areas of the basin for instance in Kirkuk No. 85 and Musaiyib No. 1.

The Rachi No. 1 well section in southern Iraq contains a number of calcareous nannofossils unique to it including; *Birkelundia staurion, Chiasmolithus solitus,* *Discoaster gemmeus, D. wemmelensis, Traversopontis obliquipons* and *T. rectipons*, which may indicate a difference in the environmental pressures effecting this nannofossil assemblage.

The concentration of certain calcareous nannofossil groups discussed above may be due to:

(1). The concentration of nannofossil groups towards the high in the northeast may of been a response to the decrease in salinity caused by the addition of freshwater into the basin as a result of runoff from the erosion of high. There is some evidence of the reduced salinity in this area as Majiid and Vieser (1986) noted that the limestones in this area were deposited in waters with a salinity between that of freshwater and seawater. The unique calcareous nannofossil assemblage in Rachi No. 1 may indicate a hyposaline environment as the sediments containing the calcareous nannofossil assemblage are associated with nummulitic limestones and anhydrites.

(2) The occurrence of more discoasters particularly the occurrence of *D. barbadiensis* and *D. saipanensis* have been linked to warm surface environments (Bukry 1971b) and the fact that the diversity of this family increases in southern Iraq possibly indicates that the surface waters were warmer in southern Iraq during this time period. This evidence fits in with the general geological setting of southern Iraq as for the much of the Palaeocene to Late Eocene shallow water, nummulitic limestones were being deposited and it was not until the Mid Eocene period when the relative sea-level had risen, perhaps as a response to tectonic activity, that environmental conditions changed so that they could now sustain restricted nannofossil assemblages.

(3) The occurrence of more Helicosphaeraceae species particularly towards the south in Musaiyib No. 1 may indicate more restricted environmental conditions. This theory for this group was originally put forward by Gartner (1977) and is discussed earlier.

(4) The concentration of certain calcareous nannofossil groups to relative high areas of the basin may be reflecting the fact that these calcareous nannofossil

groups are robust and relatively resistant to the effects of reworking allowing them to be relatively concentrated in these marginal sediments where reworking is more active.

7.2.4 Early Oligocene:

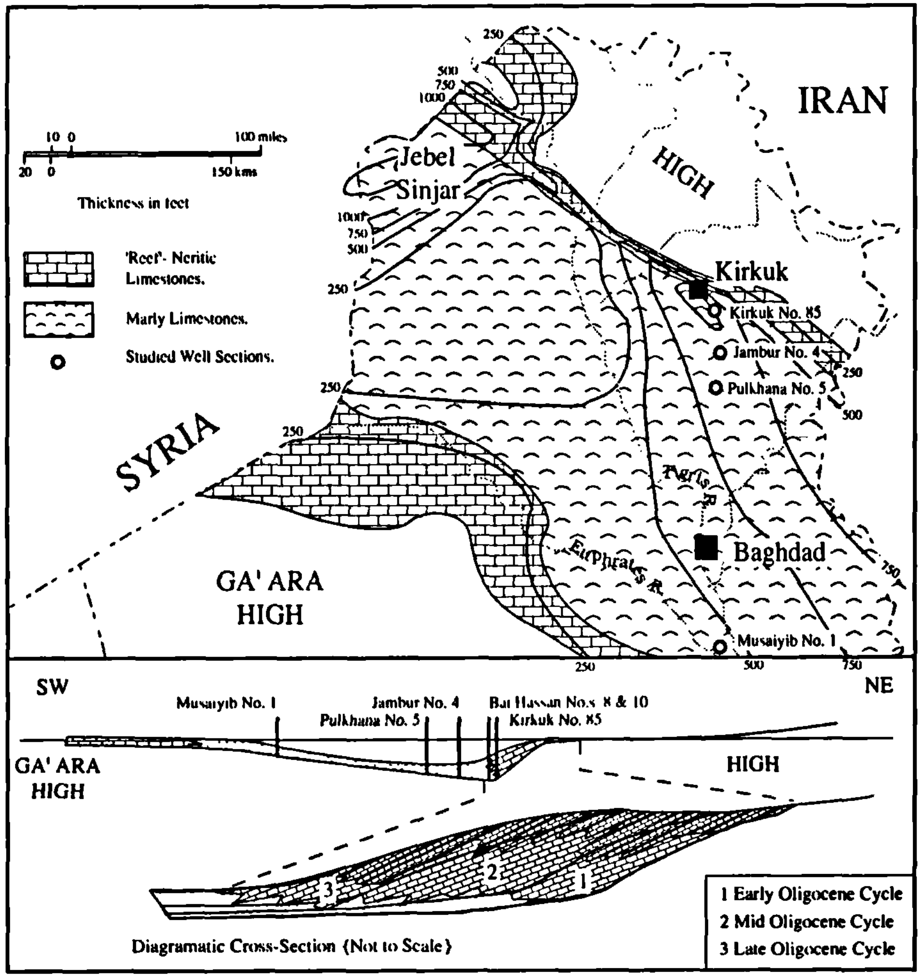
7.2.4(i) Ericsonia subdisticha Zone (IT5):

Only one zone is noted in this time period and the main features of the calcareous nannofossil assemblages noted in the well sections containing the *Ericsonia subdisticha* Zone (IT5) are illustrated in Figure 7.9 and are discussed below in detail.

- The Braarudosphaeraceae, Coccolithaceae, Noelaerhabdaceae and Discoasteraceae families have cosmopolitan occurrences through out all the well sections studied that contain this zone though, the Discoasteraceae are slightly more diverse towards the centre of the basin in Pulkhana No. 5.
- The Helicosphaeraceae and Pontosphaeraceae families increase in both diversity and abundance towards the south in Musaiyib No. 1; this is particularly evident in the former family.
- The Sphenolithaceae show an increase in abundance towards the centre of the basin in Pulkhana No. 5 and Jambur No. 4 and also show an increase in diversity towards the south in Pulkhana No. 5 and Musaiyib No. 1.
- The Rhabdolithaceae and *Zygrhablithus bijugatus* show an increase in abundance towards highs. This is noted in the north, in Kirkuk No. 85 which lies close to the high in the northeast and towards the south in Musaiyib No. 1 which lies close to the Ga'ara High.

The concentration of certain nannofossil groups in the study area may be due to:

(1). The concentration of certain nannofossil groups towards the high in the northeast may of been a response to the decrease in salinity caused by the addition of freshwater into the basin as a result of runoff from the erosion of high. There is some evidence of the reduced salinity in this area as Majiid and Vieser (1986) noted that the limestones in this area were deposited in waters with salinities inbetween that of freshwater and seawater.



Ericsonia subdisticha Zone (IT5).				
Calcareous Nannofossil Assemblage	Kirkuk No. 85	Jambur No. 4	Pulkhana No. 5	Musaiyib No. 1
Coccolithaceae	12.81%	8.94%	16.26%	15.54%
Chiasmolithus titus	X	X	X	✓
Coccolithus pelagicus	✓	✓	✓	✓
Ericsonia formosa	✓	X	✓	✓
Ericsonia obrupta	✓	X	✓	✓
Ericsonia subdisticha	✓	✓	✓	✓
Pyrocyclus hermosus	X	✓	✓	✓
Noelaerhabdaceae	58.15%	70.11%	58.30%	65.29%
Cyclicargolithus floridanus	✓	✓	✓	✓
Reticulofenestra bisecta	✓	✓	✓	✓
Reticulofenestra hillae	X	X	X	✓
Reticulofenestra minuta	X	✓	✓	✓
Reticulofenestra scrippsae	✓	✓	✓	✓
Reticulofenestra umbilica	✓	X	✓	✓
Helicosphaeraceae	2.18%	1.78%	4.40%	4.78%
Helicosphaera bramlettei	X	X	X	✓
Helicosphaera compacta	X	✓	X	✓
Helicosphaera euphratis	✓	X	✓	✓
Helicosphaera minima	X	X	X	✓
Helicosphaera wilcoxonii	X	X	✓	X
Discoasteraceae	0.43%	0.65%	0.79%	0.32%
Discoaster deflandrei	X	✓	✓	X
Discoaster tanii	✓	X	✓	X
Discoaster tanii nodifer	X	X	✓	X
Sphenolithaceae	8.68%	17.64%	15.64%	3.49%
Sphenolithus moriformis	X	X	✓	✓
Sphenolithus moriformis Group	✓	✓	✓	✓
Sphenolithus predistentus	✓	X	✓	✓
Pontosphaeraceae	1.10%	0.33%	1.10%	2.13%
Pontosphaera spp.	✓	✓	✓	✓
Pontosphaera multipora	✓	X	X	✓
Traversopontis obliquipons	X	X	X	✓
Braarudosphaeraceae	0.43%	—	0.47%	0.32%
Braarudosphaera bigelowii	✓	X	✓	✓
Micrantholithus flos	X	X	✓	X
Rhabdosphaeraceae	2.03%	—	1.09%	5.55%
Rhabdolithus spp.	✓	X	✓	✓
Calyptrosphaeraceae	3.48%	0.57%	1.09%	1.83%
Zygrhablithus bijugatus	✓	✓	✓	✓

✓ Present
X Absent
% Percentage of Total Nannofossil Assemblage

Figure 7.9 Isopach-Facies Map, Model and Calcareous Nannofossil Assemblage Data for the Oligocene of Northern Iraq (Partly Modified after Dunnington, 1958).

(2) The occurrence of more Helicosphaeraceae species particularly towards the south in Musaiyib No. 1 may indicate more restricted environmental conditions. This theory for this group was originally put forward by Gartner (1977) and is discussed earlier.

(3) The concentration of certain nannofossil groups in relative high areas of the basin may be reflecting the fact that these nannofossil groups are robust and relatively resistant to the effects of reworking allowing them to be concentrated in these marginal areas where reworking is more active.

Compared to the Late Palaeocene to Early Eocene period the Mid Eocene and Early Oligocene periods have low diversities and this might be related to global cooling as suggested by Bown *et al.* (1991, 1992).

CHAPTER EIGHT
CONCLUSIONS & RECOMMENDATIONS

8.1 Conclusions:

The conclusions of this study will be discussed under four topics; biostratigraphy, depositional history, tectonic framework and biogeography.

8.1.1 Biostratigraphy:

(1). A new calcareous nannofossil zonation has been successfully established for the Late Cretaceous to Mid Miocene based upon 515 drill cuttings, conventional core and bit samples taken from 10 well sections located in both northern and southern Iraq. In all 13 zones and 7 subzones were established for this time period. A nannofossil scheme in this detail and at this scale has never been attempted for Iraq before.

(2). The new zonation was primarily correlated to the global calcareous nannofossil zonation schemes however, more regional calcareous nannofossil zonation schemes such as offshore well sections in DSDP Legs 23 and 24, and onshore well and outcrop sections from the Commonwealth of Independent States, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Libya, Syria and Turkey have also been correlated to the new zonation. These correlations mean that the geological development of Iraq can now be placed within a global and regional stratigraphic framework.

(3). The new nannofossil zonation has also been integrated with global planktonic foraminiferal zonation schemes and both planktonic and benthonic foraminiferal zonation schemes based upon outcrop and well samples from the formations being analysed during this study. This work was carried out to assess palaeontological ages previously assigned to the formations, in light of the new calcareous nannofossil zonation scheme being produced.

(4). The new calcareous nannofossil zonation scheme was also correlated to the magnetobiostratigraphic time scale so that the sedimentation rates, durations of hiatuses and the timing of tectonic events could be assessed for Iraq during the time period studied.

8.1.2 Depositional History:

(1). The sedimentation rates during the Mid Palaeocene to Early Eocene are generally rapid being associated with a flysch trough running northwest-southeast across northern Iraq. Sedimentation in this trough was not uniform as two periods of more rapid sedimentation were recognised:

(a). The first period of increased sedimentation was as noted in the Early Eocene and was at its peak in the lowermost Early Eocene within the *Tribrachiatus contortus* A Subzone (IT9b) and the *Rhomboaster bitrifida* Subzone (IT9c) from 53.4 Ma. to 53.9 Ma.. This increased sedimentation caused the flysch trough to be filled. By *the Tribrachiatus orthostylus* Subzone (IT8c) between 50.5 Ma. and 52.5 Ma., Kolosh Clastics were being deposited on the southern margin of the flysch trough in the region of Kirkuk No. 116. However the variable nature of the sedimentation rate is illustrated by the lack of Kolosh Clastics in Pulkhana No. 5 at this time.

(b). The second period of increased sedimentation was again during the Early Eocene and is recognised in Chemchemal No. 2 within the *Discoaster kuepperi* Subzone (IT8a) and the *Sphenolithus conspicuus* Subzone (IT8b) from 50.5 Ma. to 49.0 Ma. . This increased sedimentation rate would probably have been recognised in Kirkuk No. 116 had samples been available, as the flysch trough was already full of erosion products from the high in the northeast by the end of the previous subzone.

These increased periods of sedimentation during the Early Eocene are probably the result of the high towards the northeast of Iraq supplying the sediments for the flysch trough rising more rapidly. This was probably the result of increased tectonic pressures as Tethys continued to close.

(2). The sedimentation rates during the Mid to Late Paleocene within Pulkhana No. 5 are low compared to those of the Kirkuk No. 116 and Chemchemal No. 2 which are associated with the flysch trough. The lower sedimentation rates in Pulkhana No. 5 resulted in a condensed sequence. The information on sedimentation rates confirms in detail the theory previously presented by van Bellen *et. al.* (1959), and demonstrates that the centre of the basin was sediment starved at this time. The sediment starved nature of the basin was probably the result of the combined effect of a rapidly subsiding flysch trough and the arcuate ridge towards the northeast of Iraq acting to trap sediments.

(3). During the Mid Eocene and the Oligocene to Early Miocene period the depositional history is much less complicated as no flysch trough or internal basin highs exist and as a result the sedimentation rates generally increased towards the basin centre.

8.1.3 Tectonic Framework:

(1). The proposed nannofossil biostratigraphy is influenced by the tectonic history of the Middle East and helps to confirm tectonic theories:

(a). The initial collision between the Eurasian Plate and the Arabian Plate in the Mid to Late Eocene is marked in the study area by a hiatus between the Mid Eocene *Reticulofenestra dictyoda* Zone (IT6) and the Early Oligocene *Ericsonia subdisticha* Zone (IT5) from 39.7 Ma. to 34.2 Ma. .

(b). In the Early Oligocene downwarping of the crust set-up a foreland basin which stretched from the Mediterranean through southern Turkey, northern Syria, northern Iraq and southwestern Iran into the Gulf. This narrower basin is noted in the study area since Oligocene sediments are not recorded in southern Iraq.

8.1.4 Biogeography:

(1). Concentrations of certain nannofossil groups were detected which can be related to differing environmental conditions within the basin. For example during the Mid Palaeocene to Early Eocene the Coccolithaceae and Noelaerhabdaceae appear cosmopolitan, the Sphenolithaceae was concentrated towards the centre of the basin and increases in Zygodiscaceae, *Thoracosphaera operculata*, Discoasteraceae, Fasciculithaceae and Incertae Sedis are associated with the high towards the northeast of Iraq. The increased diversity and abundance towards the high in the northeast can be linked to reduction of salinity and an increase in reworking when approaching the high. However, there is evidence within the same time period that global cooling and warming affected the nannofossil assemblages. The cooling event from the Mid to Late Palaeocene was recognised by the continued occurrence of *Prinsius martini* and the warming event in the Early Eocene was recognised by the diversity in Discoasteraceae and in particular the occurrence of *Discoaster barbadiensis*. It is believed that these global warming and cooling events did affect nannofossil assemblages over a wide area of Iraq however, the typical features of these assemblages are complicated in well sections situated close to the high in the northeast due to the effects of salinity changes and reworking.

8.2 Recommendations:

(1). The calcareous nannofossil biostratigraphy presented in this study could be improved if more outcrop material and accurately collected conventional core and side wall core material were available for study, as then both first and last appearances datums of taxa could be used to establish the zonation scheme.

(2). A more detailed assessment of the depositional history of the area could be achieved if access to wireline logs for the well sections, in particular gamma ray logs and if detailed seismic sections were available, as this would allow a sequence stratigraphic approach to taken using the calcareous nannofossil biostratigraphic data collected during this present study.

(3). The biogeography could be improved, again if more properly collected conventional core and side wall core material was available for study and if outcrop material was available, as the effects of caving from the results would be removed. The biogeography would also be improved if more well sections and outcrop sections were available to study, as then the trends noted in the calcareous nannofossil groups to checked to see if they continue as expected in other parts of the basin. In addition if more oxygen isotope studies were carried on the samples it could be assessed when global warming and cooling events occurred in the study area.

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KIRKUK No. 116.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

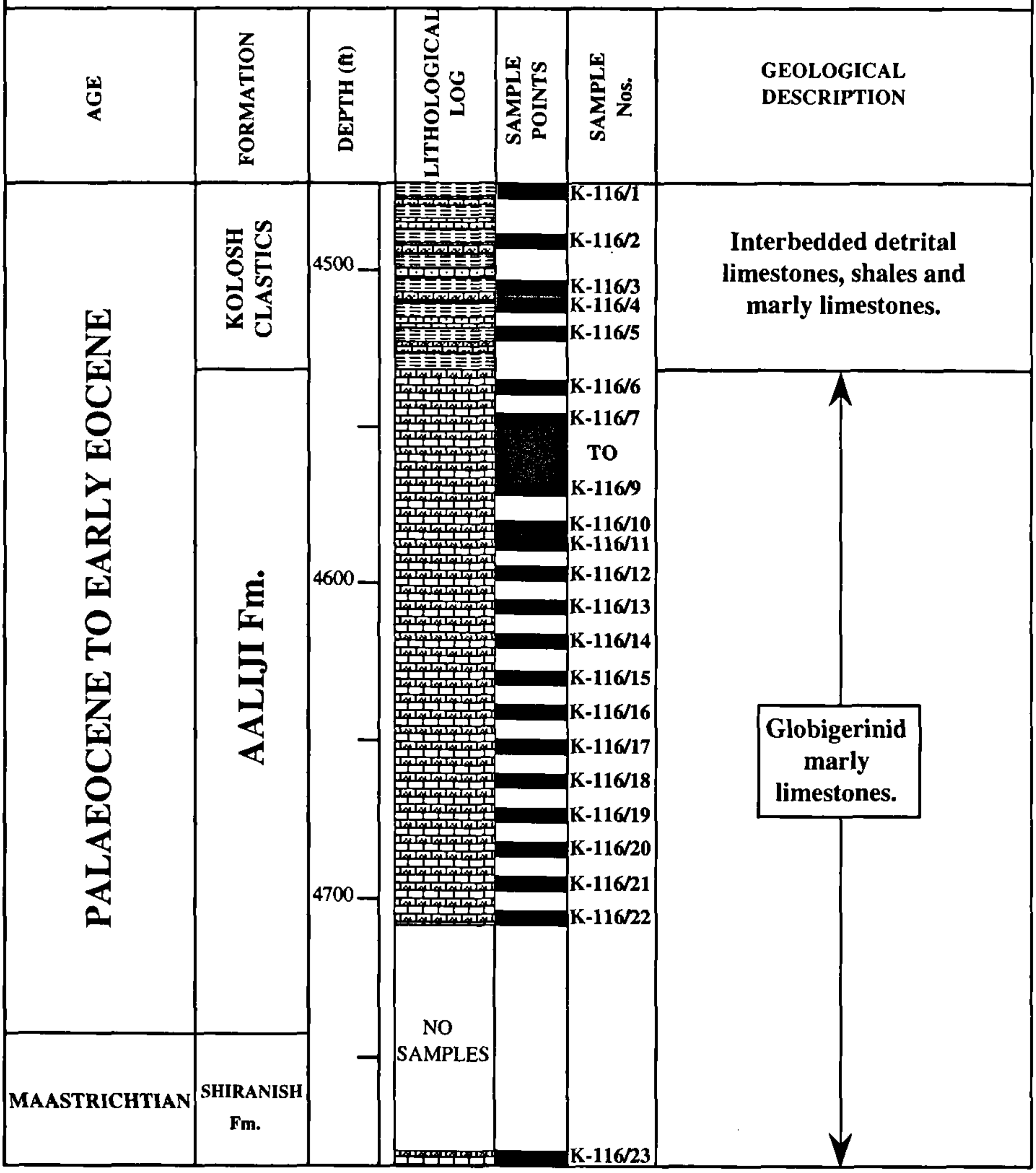
KIRKUK No. 116

LOCATION : KIRKUK FIELD NORTHERN IRAQ	
LATITUDE	35° 47' 29".00 N
LONGITUDE	43° 59' 06".30 E

LITHOLOGICAL KEY:

- MARLY LIMESTONE
- DETRITAL LIMESTONE
- SHALE

DRILLING COMMENCED	NOT STATED
DRILLING COMPLETED	NOT STATED
TOTAL DEPTH	9019 FEET (2749 METRES)



KIRKUK No. 116.

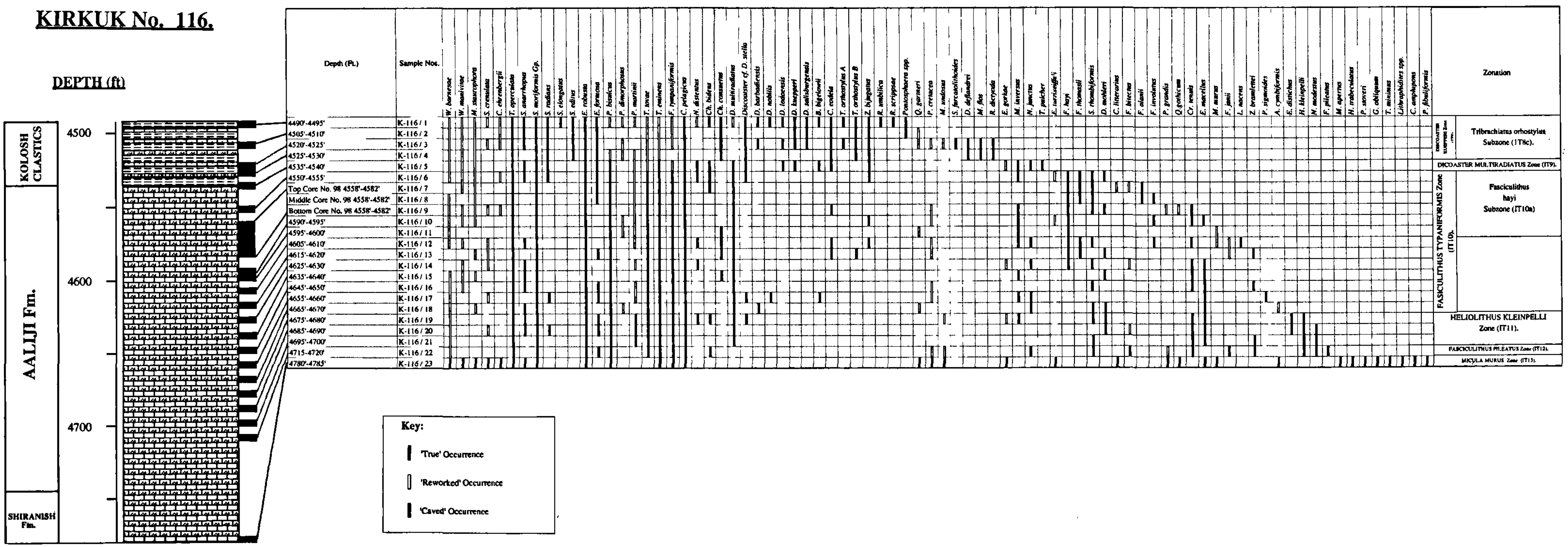
Data Sheet.

Depth (Ft.)	Sample Nos.	W. barnesae	W. manivitae	M. staurophora	R. crenulata	C. ehrenbergii	T. operculata	S. anarrhopus	S. moriformis Gp.	S. radians	S. elongatus	S. editus	E. robusta	E. formosa	P. bisulcus	P. dimorphosus	P. martinii	T. tovae	T. eminens	F. tympaniformis	C. pelagicus	N. distentus	Ch. bidens	Ch. consuetus	D. multiradiatus	Discoaster cf. D. stella	D. barbadiensis	D. nobilis
4490'-4495'	K-116 / 1	3	3	5	1	2	2	4	25	43	2	9	15	16	4	5	2	8	27	2	43	1	2	4	2	27	2	1
4505'-4510'	K-116 / 2	3	2	0	0	1	2	2	13	10	0	1	3	13	0	0	0	6	12	1	25	0	0	1	0	8	0	0
4520'-4525'	K-116 / 3	9	5	3	2	1	2	3	18	26	0	1	3	5	0	2	0	1	10	1	19	0	0	2	0	8	1	0
4525'-4530'	K-116 / 4	2	1	2	0	0	2	0	11	16	0	3	1	2	1	2	2	1	9	0	17	0	0	1	0	4	0	0
4535'-4540'	K-116 / 5	2	1	0	0	0	6	4	31	8	0	0	21	14	6	0	1	12	27	1	139	5	1	0	1	3	0	0
4550'-4555'	K-116 / 6	1	1	2	0	1	3	1	45	1	0	0	10	9	8	0	2	16	25	26	124	1	1	0	6	1	0	0
Top Core No. 98 4558'-4582'	K-116 / 7	0	2	2	0	0	1	0	11	0	0	0	12	8	17	0	11	35	32	38	106	0	2	0	3	0	0	0
Middle Core No. 98 4558'-4582'	K-116 / 8	1	0	1	0	0	5	0	12	0	0	0	20	6	26	0	3	10	78	30	82	0	0	0	4	0	0	0
Bottom Core No. 98 4558'-4582'	K-116 / 9	3	3	1	1	1	1	0	10	0	0	0	8	0	28	0	5	22	78	35	76	0	0	0	5	0	0	0
4590'-4595'	K-116 / 10	2	1	1	0	0	4	0	8	0	0	0	4	0	27	2	1	24	68	49	88	0	0	0	15	0	0	0
4595'-4600'	K-116 / 11	3	0	0	0	0	11	0	7	0	0	0	8	0	24	1	1	18	94	34	91	0	0	2	8	0	0	0
4605'-4610'	K-116 / 12	6	1	0	2	0	14	1	6	0	0	0	6	0	18	0	1	9	60	75	70	1	0	1	15	0	0	0
4615'-4620'	K-116 / 13	0	0	1	1	0	7	0	3	0	0	0	5	1	44	0	0	15	99	27	78	0	0	1	8	0	0	0
4625'-4630'	K-116 / 14	0	3	0	1	0	8	2	3	0	0	0	5	0	51	0	2	19	61	25	110	1	0	0	5	0	0	0
4635'-4640'	K-116 / 15	3	1	3	0	0	8	1	6	0	0	0	9	0	42	0	0	13	65	43	93	0	0	1	10	0	0	0
4645'-4650'	K-116 / 16	3	1	0	0	0	5	1	8	0	0	0	7	3	47	0	4	29	69	27	94	0	0	0	2	0	0	0
4655'-4660'	K-116 / 17	2	0	0	3	0	3	0	4	1	0	0	4	4	57	0	3	15	70	18	102	0	0	0	3	2	0	1
4665'-4670'	K-116 / 18	2	0	2	0	0	5	2	10	0	0	0	4	0	65	1	0	22	52	37	88	0	0	0	3	0	1	0
4675'-4680'	K-116 / 19	0	0	0	0	0	7	1	3	0	0	0	5	3	62	0	1	13	72	24	89	2	1	0	6	1	0	0
4685'-4690'	K-116 / 20	1	0	0	1	0	7	4	11	1	0	0	3	1	68	0	14	13	53	26	78	0	0	0	5	0	0	0
4695'-4700'	K-116 / 21	1	0	0	0	0	10	0	9	0	0	0	6	0	59	0	6	18	57	33	86	0	0	0	1	0	0	0
4715-4720'	K-116 / 22	3	0	0	0	0	6	0	3	0	0	0	8	1	97	0	0	19	48	9	80	0	1	0	0	0	0	0
4780'-4785'	K-116 / 23	66	39	23	16	18	15	4	3	0	0	0	3	0	4	0	0	0	3	3	4	0	0	0	0	0	0	0

Depth (Ft.)	Sample Nos.	D. lodoensis	D. kuepperi	D. salisburgensis	B. bigelowii	C. eodela	T. orthostylus A	T. orthostylus B	Z. bijugatus	R. umbilica	R. scrippsae	Pontosphaera spp.	Q. gartneri	P. cretacea	M. undosus	S. furcatolithoides	D. deflandrei	M. flos	R. dictyoda	E. gorkae	M. inversus	N. junctus	T. pulcher	E. terriseiffeli	F. hayi	F. thomasii	S. rhombiformis	D. mohleri
4490'-4495'	K-116 / 1	3	3	5	2	10	2	1	12	1	1	7	●	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4505'-4510'	K-116 / 2	0	1	2	0	4	0	2	1	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4520'-4525'	K-116 / 3	3	3	2	0	1	1	2	4	0	0	0	1	1	1	1	3	3	2	0	0	0	0	0	0	0	0	0
4525'-4530'	K-116 / 4	0	0	0	2	0	3	4	0	0	0	0	●	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
4535'-4540'	K-116 / 5	4	1	0	2	7	0	0	5	0	0	0	●	0	0	0	0	0	0	1	2	2	2	0	0	0	0	0
4550'-4555'	K-116 / 6	0	0	0	0	0	0	0	4	0	0	0	●	0	0	0	0	0	0	0	1	0	0	1	7	9	2	1
Top Core No. 98 4558'-4582'	K-116 / 7	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	0	0	0	0	0	18	6	3	0
Middle Core No. 98 4558'-4582'	K-116 / 8	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	0	0	0	0	0	7	5	2	0
Bottom Core No. 98 4558'-4582'	K-116 / 9	0	0	0	2	0	0	0	0	0	0	0	●	1	0	0	0	0	0	0	1	0	0	0	9	0	3	2
4590'-4595'	K-116 / 10	0	0	0	0	0	0	0	1	0	0	0	●	1	0	0	0	0	0	0	1	0	0	1	7	0	0	0
4595'-4600'	K-116 / 11	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0
4605'-4610'	K-116 / 12	0	0	0	0	1	0	0	1	0	0	0	●	2	0	0	0	0	0	0	2	1	0	0	9	4	2	0
4615'-4620'	K-116 / 13	0	0	0	0	3	0	1	0	0	0	0	●	2	0	0	0	0	0	0	0	0	0	0	2	1	0	1
4625'-4630'	K-116 / 14	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0
4635'-4640'	K-116 / 15	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
4645'-4650'	K-116 / 16	0	0	0	0	0	0	0	0	0	0	0	●	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0
4655'-4660'	K-116 / 17	0	0	0	1	0	0	0	0	0	0	0	●	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
4665'-4670'	K-116 / 18	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
4675'-4680'	K-116 / 19	0	0	0	0	0	0	0	0	0	0	0	●	0	1	0	0	0	0	1	2	0	0	0	0	0	1	1
4685'-4690'	K-116 / 20	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4695'-4700'	K-116 / 21	0	0	0	0	0	0	0	0	0	0	0	●	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4715-4720'	K-116 / 22	0	0	0	0	0	0	0	0	0	0	0	●	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0
4780'-4785'	K-116 / 23	0	0	0	0	0	0	0	0	0	0	0	3	6	16	0	0	0	0	3	0	0	0	3	0	0	0	0

Depth (Ft.)	Sample Nos.	C. literarius	F. bitectus	F. alanii	F. involutus	P. grandis	Q. gothicum	Cr. tenuis	E. macellus	M. murus	F. janii	L. nascens	Z. bramlettei	P. sigmoides	A. cymbiformis	E. distichus	H. kleinpelli	N. modestus	F. pileatus	M. apertus	H. trabeculatus	P. stoveri	G. obliquum	T. phacelosus	Lithraphidites spp.	C. amphipons	P. fibuliformis	Total	Preservation State	No. of Nannofossils per Field of View
4490'-4495'	K-116 / 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	307	2.5	0.108
4505'-4510'	K-116 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	116	2.5	0.041
4520'-4525'	K-116 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	2.5	0.053
4525'-4530'	K-116 / 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	2.5	0.031
4535'-4540'	K-116 / 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	309	2.5	0.785
4550'-4555'	K-116 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	309	2.5	1.431
Top Core No. 98 4558'-4582'	K-116 / 7	1	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312	2.5	2.232
Middle Core No. 98 4558'-4582'	K-116 / 8	0	0	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	301	2.5	9.438
Bottom Core No. 98 4558'-4582'	K-116 / 9	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	301	2.5	16.67
4590'-4595'	K-116 / 10	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	309	2	25.75
4595'-4600'	K-116 / 11	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	309	2	20.6
4605'-4610'	K-116 / 12	0	0	0	1	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	313	2.5	5.048
4615'-4620'	K-116 / 13	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	303	2	15.9
4625'-4630'	K-116 / 14	0	3	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	307	2	6.674
4635'-4640'	K-116 / 15	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	2	16.05
4645'-4650'	K-116 / 16	0	0	0	0	0	0	6	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312	2	9.719
4655'-4660'	K-116 / 17	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	1.5	9.677
4665'-4670'	K-116 / 18	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	302	1.5	2.849
4675'-4680'	K-116 / 19	0	0	0	0	0	0	3	1	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	305	1.5	8.472
4685'-4690'	K-116 / 20	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	1	7	0	0	0	0	0	0	0	0	0	300	1.5	6.977
4695'-4700'	K-116 / 21	0	0	0	0	0	0	1	3	0	0	0	2	0	0	0	6	2	0	0	0	0	0	0	0	0	0	301	2	12
4715-4720'	K-116 / 22	0	1	0	0	1	0	2	0	0	2	0	1	0	0	0	5	6	3	0	0	0	0	0	0	0	0	300	2	8.108
4780'-4785'	K-116 / 23	2	0	0	0	6	4	0	2	3	0	0	0	0	6	0	0	0	0	4	3	2	3	4	23	3	3	300	2	7.143

RANGE CHART

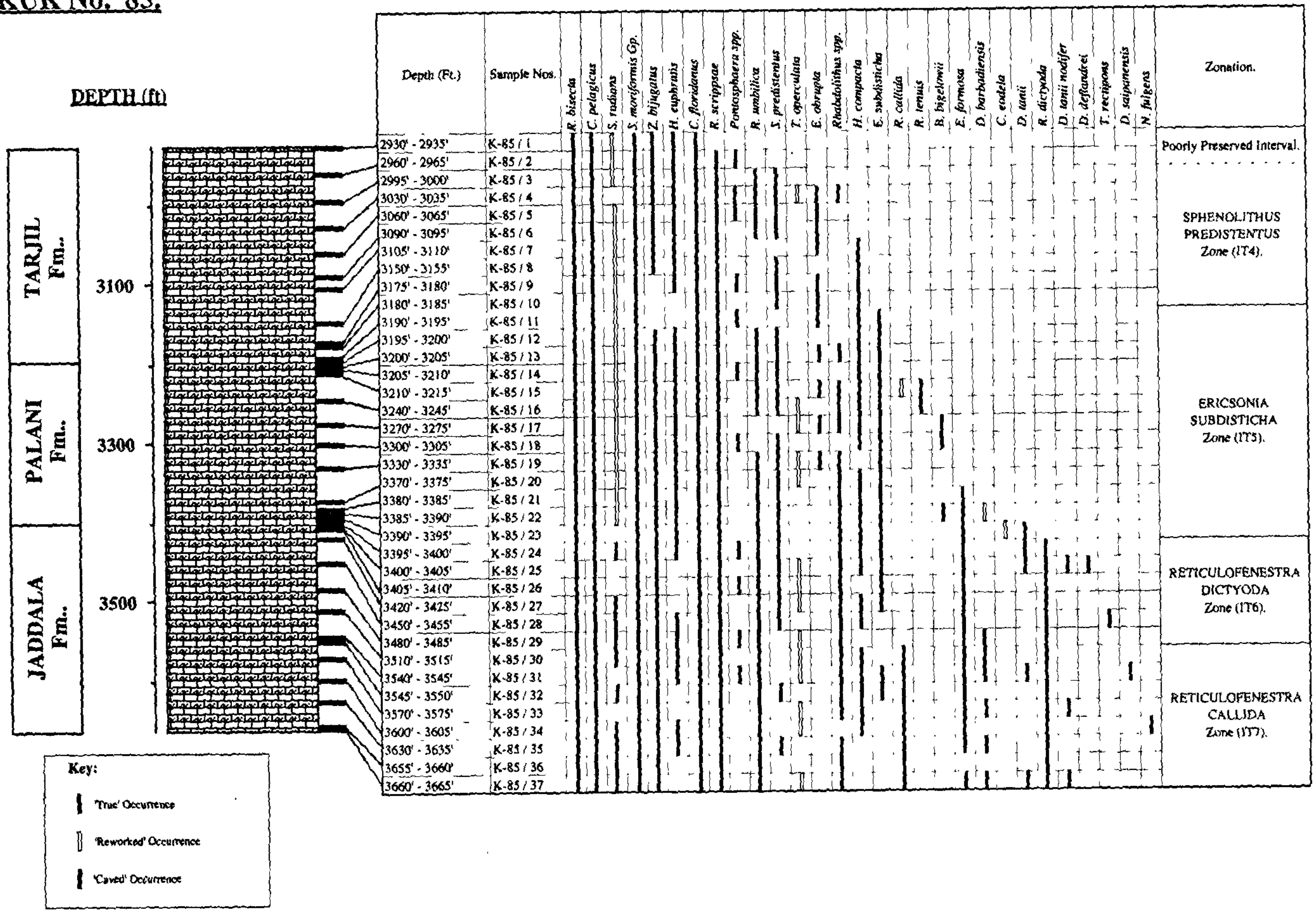


KIRKUK No. 85.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

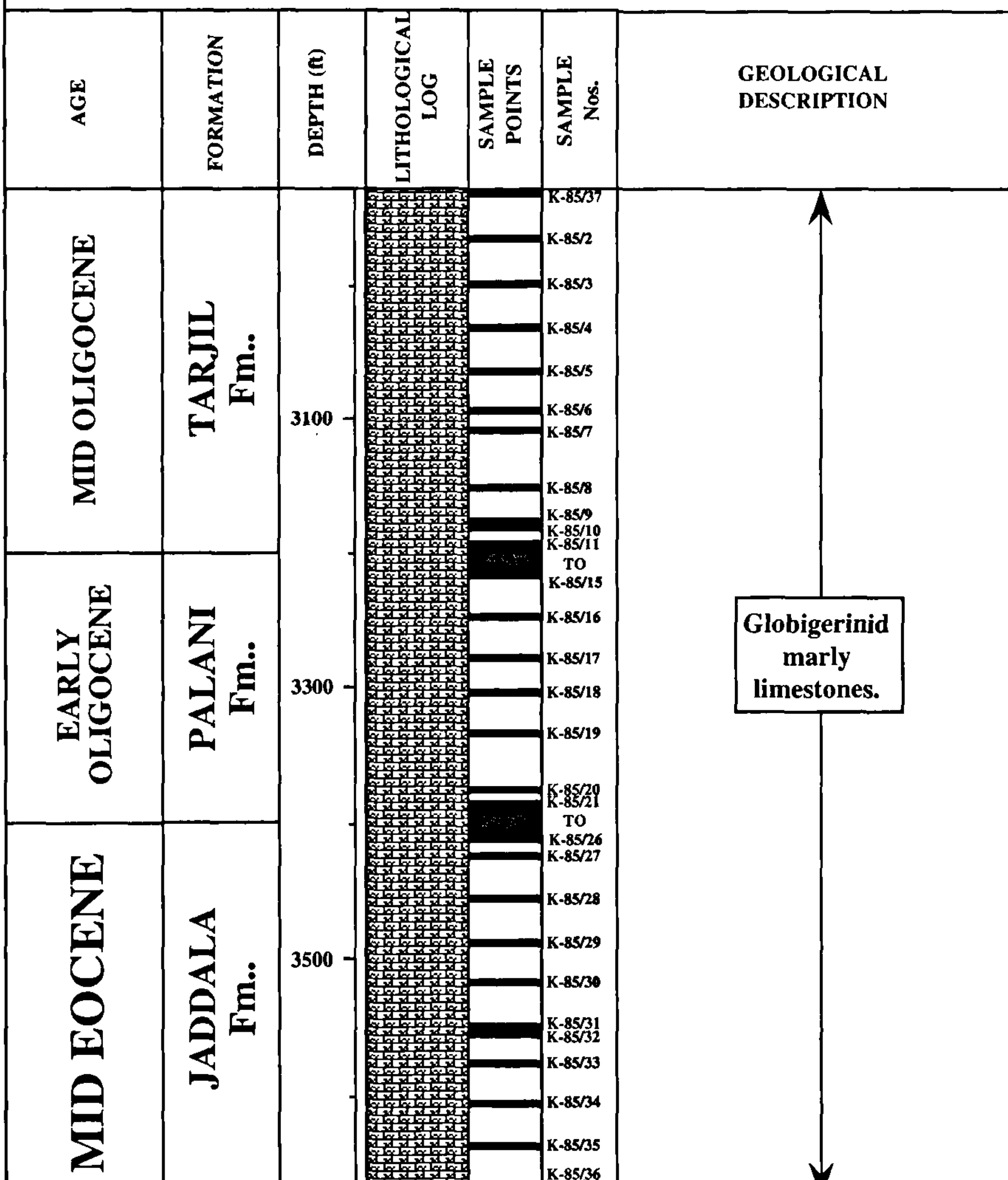
Range Chart

KIRKUK No. 85.



KIRKUK No. 85

LOCATION : KIRKUK FIELD NORTHERN IRAQ		**LITHOLOGICAL KEY:** MARLY LIMESTONE	
LATITUDE	36° 26' 42"N	DRILLING COMMENCED	NOT STATED
LONGITUDE	44° 25' 28"E	DRILLING COMPLETED	NOT STATED
		TOTAL DEPTH	3670 FEET (1100 METRES)



KIRKUK No. 85

Data Sheet.

Depth (Ft.)	Sample Nos.	R. bisecta	C. pelagicus	S. radians	S. moriformis Gp.	Z. bijugatus	H. euphratis	C. floridanus	R. scrippsae	Pontosphaera spp.	R. umbilica	S. predistentus	T. operculata	E. obrupta	Rhabdolithus spp.	H. compacta	E. subdisticha	R. callida	R. tenuis	B. bigelowii	E. formosa	D. barbadiensis	C. eodela	D. tanii	R. dictyoda	D. tanii nodifer	D. deflandrei	T. rectipons	D. saipanensis	N. fulgens	Total	Presevation State	No. Nannofossils per Field of View
2930' - 2935'	K-85 / 1	55	5	2	16	11	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	2.5	0.038
2960' - 2965'	K-85 / 2	145	20	2	37	6	2	86	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	302	2.5	0.839
2995' - 3000'	K-85 / 3	146	25	5	38	5	3	63	15	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	2.5	0.941
3030' - 3035'	K-85 / 4	53	38	0	30	6	1	134	37	2	2	3	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	310	2.5	1.192
3060' - 3065'	K-85 / 5	114	38	14	38	3	2	78	17	2	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312	2.5	0.966
3090' - 3095'	K-85 / 6	149	20	6	36	4	1	66	15	0	1	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	2.5	1.143
3105' - 3110'	K-85 / 7	160	36	4	41	1	3	53	9	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	311	2.5	1.319
3150' - 3155'	K-85 / 8	148	12	6	36	2	2	85	8	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	2.5	2.230
3175' - 3180'	K-85 / 9	166	10	7	42	0	2	63	8	1	0	4	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	306	2.5	1.299
3180' - 3185'	K-85 / 10	193	17	1	50	0	0	38	3	0	0	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	306	2.5	1.643
3190' - 3195'	K-85 / 11	163	18	2	35	0	0	72	6	2	0	0	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	303	2.5	1.111
3195' - 3200'	K-85 / 12	133	26	2	30	6	1	81	15	0	2	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	301	2.5	3.179
3200' - 3205'	K-85 / 13	129	29	2	19	8	2	74	23	0	2	3	0	2	3	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	302	2.5	3.393
3205' - 3210'	K-85 / 14	102	34	6	32	32	4	48	26	1	2	12	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	307	2.5	3.416
3210' - 3215'	K-85 / 15	103	37	6	22	20	3	69	19	0	1	17	0	3	3	2	6	1	1	0	0	0	0	0	0	0	0	0	0	0	313	2.5	3.640
3240' - 3245'	K-85 / 16	119	24	2	32	13	1	69	21	0	4	6	1	0	2	2	3	0	2	0	0	0	0	0	0	0	0	0	0	0	301	2.5	3.659
3270' - 3275'	K-85 / 17	131	30	3	21	8	8	55	29	0	0	0	1	2	6	2	3	0	0	2	0	0	0	0	0	0	0	0	0	0	301	2.5	3.344
3300' - 3305'	K-85 / 18	112	40	6	13	12	2	79	29	2	0	4	0	0	0	4	2	0	0	1	0	0	0	0	0	0	0	0	0	0	306	2.5	2.267
3330' - 3335'	K-85 / 19	121	46	0	10	5	8	67	22	0	2	10	3	2	7	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	305	2.5	3.112
3370' - 3375'	K-85 / 20	141	51	2	12	6	6	47	25	0	2	6	1	0	5	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	311	2.5	3.793
3380' - 3385'	K-85 / 21	102	55	3	33	11	9	47	30	0	8	2	0	0	5	6	3	0	0	0	1	0	0	0	0	0	0	0	0	0	315	2.5	6.300
3385' - 3390'	K-85 / 22	77	60	2	30	17	7	46	30	0	5	6	0	0	16	4	5	0	0	1	1	2	0	0	0	0	0	0	0	0	309	2.5	7.537
3390' - 3395'	K-85 / 23	53	59	0	32	16	8	46	48	0	3	7	0	0	14	3	8	0	0	0	1	0	1	1	0	0	0	0	0	0	300	2.5	3.529
3395' - 3400'	K-85 / 24	83	67	4	31	15	6	31	34	1	5	7	0	0	6	4	5	0	0	0	4	0	0	1	3	0	0	0	0	0	307	2.5	4.135
3400' - 3405'	K-85 / 25	44	71	0	16	9	0	23	74	0	14	5	2	0	6	5	2	0	0	0	10	0	0	1	16	1	1	0	0	0	300	2.5	4.296
3405' - 3410'	K-85 / 26	23	50	0	16	24	0	33	107	2	7	8	1	0	3	0	3	0	0	0	8	0	0	0	16	0	0	0	0	0	301	2.5	4.054
3420' - 3425'	K-85 / 27	14	71	1	37	37	0	8	88	0	13	4	1	0	3	7	3	0	0	0	3	0	0	0	10	0	0	0	0	0	300	2.5	5.172
3450' - 3455'	K-85 / 28	24	57	2	41	24	1	12	125	0	5	1	0	0	2	3	0	0	0	0	4	0	0	0	3	0	0	1	0	0	305	2.5	4.552
3480' - 3485'	K-85 / 29	25	77	3	17	12	1	12	125	1	8	0	3	0	1	0	0	0	0	0	10	5	0	0	5	0	0	0	0	0	305	2.5	1.109
3510' - 3515'	K-85 / 30	22	52	1	36	15	1	8	123	0	6	0	1	0	1	2	0	15	0	0	8	5	0	0	4	0	0	0	0	0	300	2.5	3.370
3540' - 3545'	K-85 / 31	11	50	0	11	28	1	23	122	2	7	0	1	0	1	3	2	31	0	0	5	4	0	1	3	0	0	0	2	0	308	2.5	3.400
3545' - 3550'	K-85 / 32	10	40	3	14	29	0	25	130	0	9	2	0	0	3	3	2	12	0	0	10	0	0	0	8	0	0	0	0	0	300	2.5	3.704
3570' - 3575'	K-85 / 33	19	38	0	16	15	0	39	110	0	4	0	2	0	2	2	0	38	0	0	7	1	0	0	8	1	0	0	0	0	302	2.5	3.367
3600' - 3605'	K-85 / 34	52	41	5	20	8	2	8	124	0	8	0	1	0	0	4	0	13	0	0	12	0	0	0	3	0	0	0	0	2	303	2.5	4.208
3630' - 3635'	K-85 / 35	38	45	4	32	12	3	9	133	0	5	2	0	0	4	0	0	5	0	0	8	1	0	0	3	0	0	0	0	0	304	2.5	2.868
3655' - 3660'	K-85 / 36	25	35	3	20	20	0	10	150	0	2	0	0	0	2	0	0	30	0	0	0	0	0	0	3	0	0	0	0	0	300	2.5	2.876
3660' - 3665'	K-85 / 37	22	50	4	35	20	0	13	97	0	2	0	4	0	3	0	0	36	0	0	10	2	0	1	5	2	0	0	0	0	306	2.5	4.192

BAI HASSAN No. 10.

KEY: Abundance Rating	No. of Nannofossils per Field of View	Preservation State	Description
Very Low	< 1.0	E-3	Highly Etched
Low	1-10	E-2	Moderately Etched
Moderate	> 10-20	E-1	Slightly Etched
High	>20-30	X	Excellent
Very High	+30	O-1	Slightly Overgrown
		O-2	Moderately Overgrown
		O-3	Heavily Overgrown

BAI HASSAN No. 10 Data Sheet.

Depth (Ft.)	Sample Nos.	Q. garneri	C. pelagicus	R. bisecta	R. productus	C. floridanus	W. marivitae	M. murus	S. moriformis Gp.	E. formosa	T. eminens	Z. bijugatus	R. minuta	R. hagii	C. abisectus	S. radians	S. distentus	R. scrippsae	S. heteromorphus	P. grandis	M. inversus	E. robusta	E. subdisticha	F. tympaniformis	D. tanii nodifer	D. deflandrei	D. adamanteus	Pontosphaera spp.	P. multipora	H. euphratis	H. scissura	W. barnesae	C. macintyrei	Total	Preservation State	No. Nannofossils per Field of View
3850' - 3855'	BH-10 / 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No.2 3875' - 3893'	BH-10 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No.2 3875' - 3893'	BH-10 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3910' - 3915'	BH-10 / 4	2	7	8	4	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.018
3945' - 3950'	BH-10 / 5	1	39	17	48	152	1	1	23	3	1	4	24	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.635
3965' - 3970'	BH-10 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
4000' - 4005'	BH-10 / 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 3 4030' - 4048'	BH-10 / 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 3 4030' - 4048'	BH-10 / 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 3 4030' - 4048'	BH-10 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No.4 4048' - 4060'	BH-10 / 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No.4 4048' - 4060'	BH-10 / 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No.5 4066' - 4084'	BH-10 / 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No.5 4066' - 4084'	BH-10 / 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No.5 4066' - 4084'	BH-10 / 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 6 4084' - 4102'	BH-10 / 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 6 4084' - 4102'	BH-10 / 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 6 4084' - 4102'	BH-10 / 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 7 4102' - 4120'	BH-10 / 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 7 4102' - 4120'	BH-10 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 8 4120' - 4138'	BH-10 / 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 8 4120' - 4138'	BH-10 / 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 8 4120' - 4138'	BH-10 / 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 9 4138' - 4174'	BH-10 / 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 9 4138' - 4174'	BH-10 / 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 9 4138' - 4174'	BH-10 / 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 10 4174' - 4228'	BH-10 / 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 10 4174' - 4228'	BH-10 / 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 10 4174' - 4228'	BH-10 / 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 11 4228' - 4280'	BH-10 / 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 11 4228' - 4280'	BH-10 / 31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 11 4228' - 4280'	BH-10 / 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 12 4280' - 4310'	BH-10 / 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 12 4280' - 4310'	BH-10 / 34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 12 4280' - 4310'	BH-10 / 35	0	26	16	0	194	0	0	39	0	0	5	0	0	18	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0.39
Top Core No. 13 4310' - 4325'	BH-10 / 36	0	18	59	0	154	0	0	42	1	0	2	0	0	18	2	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2.5	0.399
Middle Core No. 13 4310' - 4325'	BH-10 / 37	0	24	36	0	165	0	0	38	1	0	0	0	0	34	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2.5	0.387
Bottom Core No. 13 4310' - 4325'	BH-10 / 38	0	8	48	0	204	0	0	10	0	0	0	0	0	29	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.5	0.105
4360' - 4365'	BH-10 / 39	0	23	23	11	192	0	0	19	1	0	3	0	2	6	0	3	3	1	1	1	1	1	1	1	1	2	1	1	3	4	0	0	25	2.5	2.675
4420' - 4425'	BH-10 / 40	0	42	11	26	156	0	0	44	0	0	0	0	0	6	0	4	0	3	0	0	0	0	0	0	2	0	2	0	2	0	1	1	15	2.5	0.459

BAI HASSAN No. 10

LOCATION :

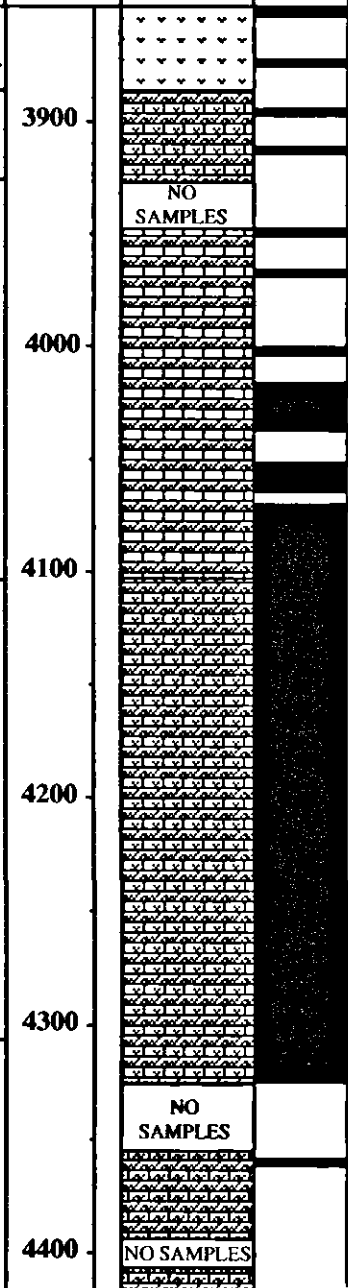
BAI HASSAN FIELD
NORTHERN IRAQ

LATITUDE	35° 35' 47".23
LONGITUDE	44° 02' 24".43

LITHOLOGICAL KEY:

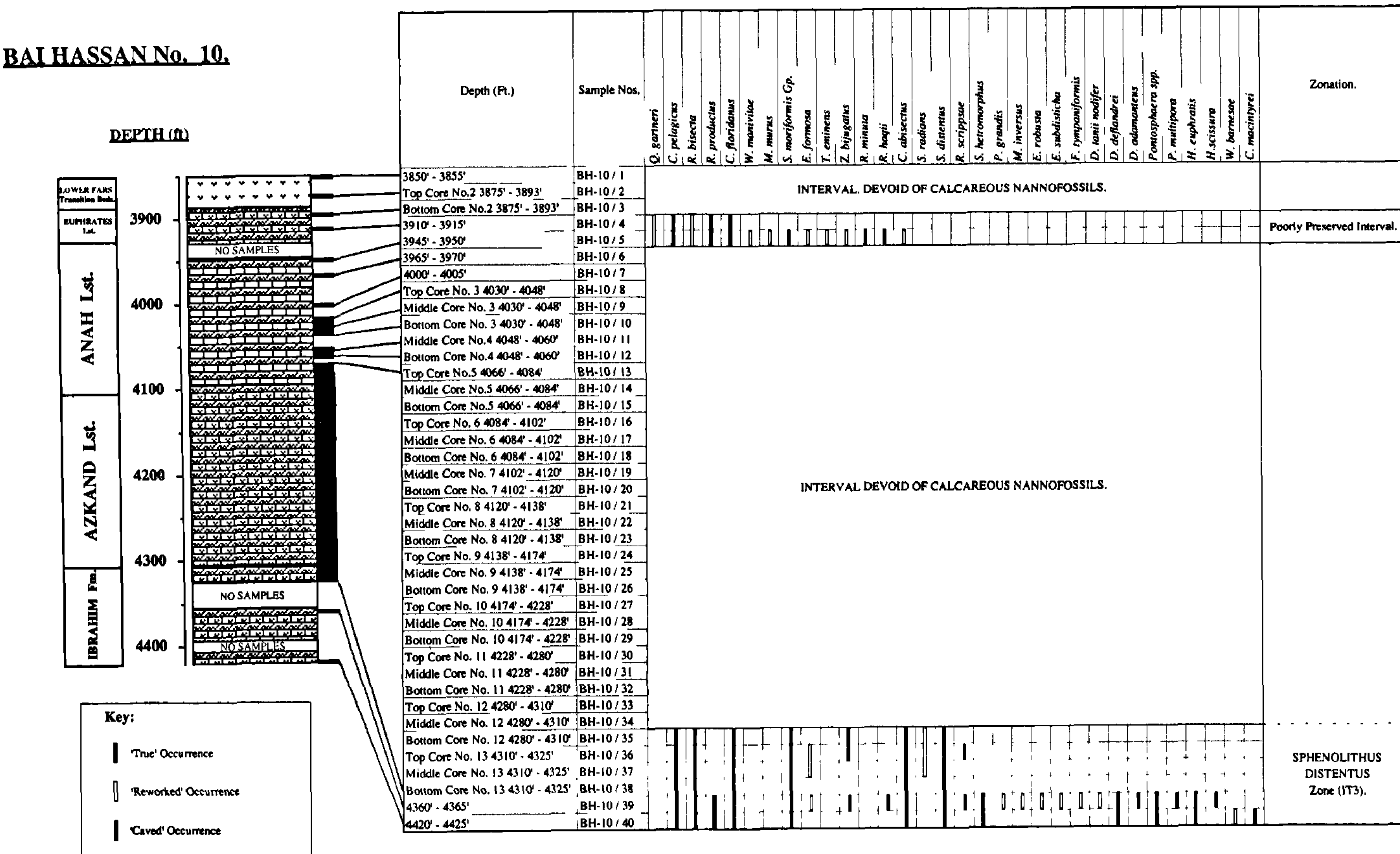
- ANHYDRITE
- LIMESTONE
- MARLY LIMESTONE
- DOLOMITE

DRILLING COMMENCED	3rd. AUGUST 1956
DRILLING COMPLETED	5th. OCTOBER 1956
TOTAL DEPTH	4460 FEET (1338 METRES)



AGE	FORMATION	SAMPLE Nos.	GEOLOGICAL DESCRIPTION
EARLY TO MID MIOCENE	LOWER FARS Transition Beds.	BH-10/1, BH-10/2	Bluish-grey, marly, locally silty, dolomitic, pyritic, flocculithic limestone with a marl on top. Ahydritization common.
	EUPHRATES Lst.	BH-10/3, BH-10/4	Grey, cream below strongly recrystallised, dolomitic, anhydritic, saccharoidal limestone. The base of this limestone is white dense, marly and lagoonal containing rotalids, miliolids, molluscs and flocculiths.
LATE OLIGOCENE	ANAH Lst.	BH-10/5	White, marly, dense, lagoonal, recrystallised limestones containg miliolids, rotalids, ostracods, molluscans and *Myogysinoides* sp.
		BH-10/6, BH-10/7	Grey to white, recrystallised, dolomitic, locally flocculitic, vuggy limestone with calcite veins. This limestone contains a back reef fauna of *Austrotrillina howchini*, *Tubicellaria* sp., lithophyllids, compound corals rare *Lepidocyclina* ghosts, *Archaias kirkukensis*, *Myogypsina* sp. at its base.
		BH-10/8 to BH-10/10, BH-10/11, BH-10/12	Grey, marly, finely vuggy, completely recrystallised, dolomitic limestone, with interstitual anhydrite nodules at its base. This limestone also contains rare ghosts of corals, *Rotalia viennoti* and echinoides. Dolomite band at 4040 feet with a reef band below to 4043 feet.
	AZKAND Lst.	BH-10/13 to BH-10/38	Greyish-brown, heavily recrystallised, porous, dolomitic but marly in parts forereef limestone. The limestone is saturated in oil and interstitual anhydrite reduces porosity. The limestone is leached in parts anhs steep irregular fractures. The forereef limestones contains floods of *Rotalia viennoti*, *Heterostegina assilinoides*, large lepidocyclinids (*Eulepidina* sp.) at the top, with *Myogypsina* sp. above 4219 feet. The limestone also contains echinoids, bryozoa, lithophyllids and buliminids at the base.
	IBRAHIM Fm.	BH-10/39	Greyish-brown, dense, marly, dolomitic limestone that is locally banded and contains vugs towards its top. The limestones also contain globigerinids, buliminids, *Nonion* sp., ostracods and shell debris.

Range Chart



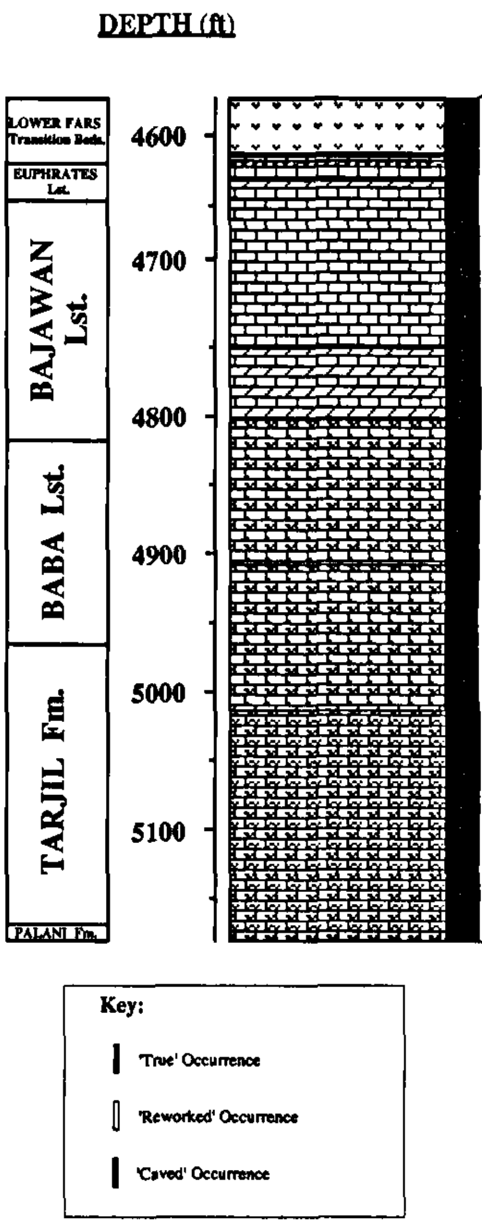
BAI HASSAN No. 10.
DEPTH (ft)
LOWER FARS Transition Beds
EUPHRATES Lst.
ANAH Lst.
AZKAND Lst.
IBRAHIM Fm.
3900
4000
4100
4200
4300
4400
NO SAMPLES
NO SAMPLES
NO SAMPLES
Depth (Ft.)
Sample Nos.
Q. garneri
C. pelagicus
R. bisecta
R. productus
C. floridanus
W. maniviae
M. murus
S. moriformis Gp.
E. formosa
T. eminens
Z. bijugatus
R. minuta
R. haqii
C. abisectus
S. radians
S. distentus
R. scrippsae
S. heteromorphus
P. grandis
M. inversus
E. robusta
E. subdisticha
F. tympaniformis
D. tanii nodifer
D. deflandrei
D. adamanteus
Pontosphaera spp.
P. multipora
H. euphratis
H. scissura
W. barnesae
C. macintyrei
Zonation.
3850' - 3855' BH-10 / 1
Top Core No.2 3875' - 3893' BH-10 / 2
Bottom Core No.2 3875' - 3893' BH-10 / 3
3910' - 3915' BH-10 / 4
3945' - 3950' BH-10 / 5
3965' - 3970' BH-10 / 6
4000' - 4005' BH-10 / 7
Top Core No. 3 4030' - 4048' BH-10 / 8
Middle Core No. 3 4030' - 4048' BH-10 / 9
Bottom Core No. 3 4030' - 4048' BH-10 / 10
Middle Core No.4 4048' - 4060' BH-10 / 11
Bottom Core No.4 4048' - 4060' BH-10 / 12
Top Core No.5 4066' - 4084' BH-10 / 13
Middle Core No.5 4066' - 4084' BH-10 / 14
Bottom Core No.5 4066' - 4084' BH-10 / 15
Top Core No. 6 4084' - 4102' BH-10 / 16
Middle Core No. 6 4084' - 4102' BH-10 / 17
Bottom Core No. 6 4084' - 4102' BH-10 / 18
Middle Core No. 7 4102' - 4120' BH-10 / 19
Bottom Core No. 7 4102' - 4120' BH-10 / 20
Top Core No. 8 4120' - 4138' BH-10 / 21
Middle Core No. 8 4120' - 4138' BH-10 / 22
Bottom Core No. 8 4120' - 4138' BH-10 / 23
Top Core No. 9 4138' - 4174' BH-10 / 24
Middle Core No. 9 4138' - 4174' BH-10 / 25
Bottom Core No. 9 4138' - 4174' BH-10 / 26
Top Core No. 10 4174' - 4228' BH-10 / 27
Middle Core No. 10 4174' - 4228' BH-10 / 28
Bottom Core No. 10 4174' - 4228' BH-10 / 29
Top Core No. 11 4228' - 4280' BH-10 / 30
Middle Core No. 11 4228' - 4280' BH-10 / 31
Bottom Core No. 11 4228' - 4280' BH-10 / 32
Top Core No. 12 4280' - 4310' BH-10 / 33
Middle Core No. 12 4280' - 4310' BH-10 / 34
Bottom Core No. 12 4280' - 4310' BH-10 / 35
Top Core No. 13 4310' - 4325' BH-10 / 36
Middle Core No. 13 4310' - 4325' BH-10 / 37
Bottom Core No. 13 4310' - 4325' BH-10 / 38
4360' - 4365' BH-10 / 39
4420' - 4425' BH-10 / 40
INTERVAL. DEVOID OF CALCAREOUS NANNOFOSSILS.
Poorly Preserved Interval.
INTERVAL DEVOID OF CALCAREOUS NANNOFOSSILS.
SPHENOLITHUS DISTENTUS Zone (IT3).
Key:
'True' Occurrence
'Reworked' Occurrence
'Caved' Occurrence

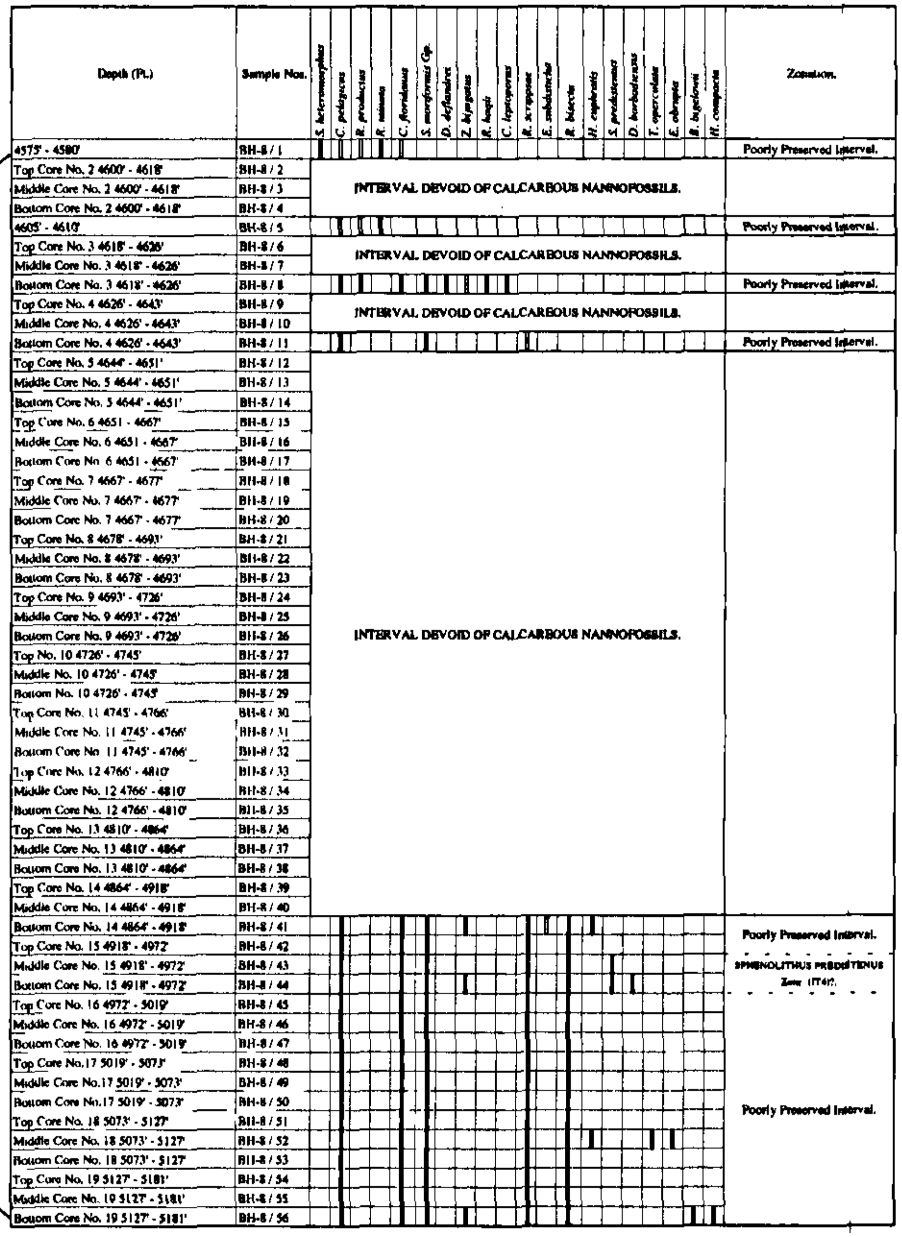
BAI HASSAN No. 8.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

Range Chart

BAI HASSAN No. 8.





BAI HASSAN No. 8. Data Sheet.

Depth (Ft.)	Sample Nos.	*S. heteromorphus*	*C. pelagicus*	*R. productus*	*R. minuta*	*C. floridanus*	*S. moriformis Gp.*	*D. deflandrei*	*Z. bijugatus*	*R. haqii*	*C. leptoporus*	*R. scrippsae*	*E. subdisticha*	*R. bisecta*	*H. euphratis*	*S. predistentus*	*D. barbadiensis*	*T. operculata*	*E. obrupta*	*B. bigelowii*	*H. compacta*	Total	Preservation State	No. Nannofossils per Field of View
4575' - 4580'	BH-8 / 1	4	10	36	15	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	2	0.023
Top Core No. 2 4600' - 4618'	BH-8 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 2 4600' - 4618'	BH-8 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 2 4600' - 4618'	BH-8 / 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
4605' - 4610'	BH-8 / 5	0	10	15	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	2	0.01
Top Core No. 3 4618' - 4626'	BH-8 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 3 4618' - 4626'	BH-8 / 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 3 4618' - 4626'	BH-8 / 8	0	47	56	0	7	44	3	6	6	3	0	0	0	0	0	0	0	0	0	0	172	2	0.06
Top Core No. 4 4626' - 4643'	BH-8 / 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 4 4626' - 4643'	BH-8 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 4 4626' - 4643'	BH-8 / 11	0	3	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	8	2	0.003
Top Core No. 5 4644' - 4651'	BH-8 / 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 5 4644' - 4651'	BH-8 / 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 5 4644' - 4651'	BH-8 / 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 6 4651 - 4667'	BH-8 / 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 6 4651 - 4667'	BH-8 / 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 6 4651 - 4667'	BH-8 / 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 7 4667' - 4677'	BH-8 / 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 7 4667' - 4677'	BH-8 / 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 7 4667' - 4677'	BH-8 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 8 4678' - 4693'	BH-8 / 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 8 4678' - 4693'	BH-8 / 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 8 4678' - 4693'	BH-8 / 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 9 4693' - 4726'	BH-8 / 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 9 4693' - 4726'	BH-8 / 25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 9 4693' - 4726'	BH-8 / 26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top No. 10 4726' - 4745'	BH-8 / 27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle No. 10 4726' - 4745'	BH-8 / 28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom No. 10 4726' - 4745'	BH-8 / 29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 11 4745' - 4766'	BH-8 / 30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 11 4745' - 4766'	BH-8 / 31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 11 4745' - 4766'	BH-8 / 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 12 4766' - 4810'	BH-8 / 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 12 4766' - 4810'	BH-8 / 34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 12 4766' - 4810'	BH-8 / 35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 13 4810' - 4864'	BH-8 / 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 13 4810' - 4864'	BH-8 / 37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 13 4810' - 4864'	BH-8 / 38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Top Core No. 14 4864' - 4918'	BH-8 / 39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Middle Core No. 14 4864' - 4918'	BH-8 / 40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
Bottom Core No. 14 4864' - 4918'	BH-8 / 41	0	49	0	0	90	29	0	1	0	0	14	1	115	1	0	0	0	0	0	0	300	2.5	0.577
Top Core No. 15 4918' - 4972'	BH-8 / 42	0	24	0	0	30	16	0	0	0	0	6	0	27	0	0	0	0	0	0	0	103	2.5	0.036
Middle Core No. 15 4918' - 4972'	BH-8 / 43	0	40	0	0	42	20	0	0	0	0	8	0	41	0	2	0	0	0	0	0	153	2.5	0.053
Bottom Core No. 15 4918' - 4972'	BH-8 / 44	0	74	0	0	80	19	0	9	0	0	9	0	103	0	4	3	0	0	0	0	301	2.5	0.386
Top Core No. 16 4972' - 5019'	BH-8 / 45	0	29	0	0	106	30	0	0	0	0	14	0	124	0	0	0	0	0	0	0	303	2.5	0.583
Middle Core No. 16 4972' - 5019'	BH-8 / 46	0	81	0	0	82	41	0	0	0	0	11	0	86	0	0	0	0	0	0	0	301	2.5	0.289
Bottom Core No. 16 4972' - 5019'	BH-8 / 47	0	24	0	0	141	16	0	0	0	0	15	0	108	0	0	0	0	0	0	0	304	2.5	0.39
Top Core No.17 5019' - 5073'	BH-8 / 48	0	41	0	0	110	19	0	0	0	0	9	0	122	0	0	0	0	0	0	0	301	2.5	0.232
Middle Core No.17 5019' - 5073'	BH-8 / 49	0	35	0	0	125	16	0	0	0	0	11	0	124	0	0	0	0	0	0	0	311	2.5	0.299
Bottom Core No.17 5019' - 5073'	BH-8 / 50	0	31	0	0	119	18	0	0	0	0	9	0	132	0	0	0	0	0	0	0	309	2.5	0.396
Top Core No. 18 5073' - 5127'	BH-8 / 51	0	35	0	0	98	63	0	0	0	0	16	0	92	0	0	0	0	0	0	0	304	2.5	0.234
Middle Core No. 18 5073' - 5127'	BH-8 / 52	0	19	0	0	164	35	0	0	0	0	30	0	36	2	0	0	2	2	0	0	290	2.5	2.857
Bottom Core No. 18 5073' - 5127'	BH-8 / 53	0	23	0	0	162	32	0	0	0	0	20	0	63	0	0	0	0	0	0	0	300	2.5	1.154
Top Core No. 19 5127' - 5181'	BH-8 / 54	0	23	0	0	143	24	0	0	0	0	14	0	122	0	0	0	0	0	0	0	326	2.5	0.418
Middle Core No. 19 5127' - 5181'	BH-8 / 55	0	27	0	0	150	32	0	0	0	0	32	0	62	0	0	0	0	0	0	0	303	2.5	0.583
Bottom Core No. 19 5127' - 5181'	BH-8 / 56	0	29	0	0	81	39	0	2	0	0	60	0	112	0	0	0	0	0	1	2	326	2.5	2.608

BAI HASSAN No. 8

LOCATION :

BAI HASSAN FIELD
NORTHERN IRAQ

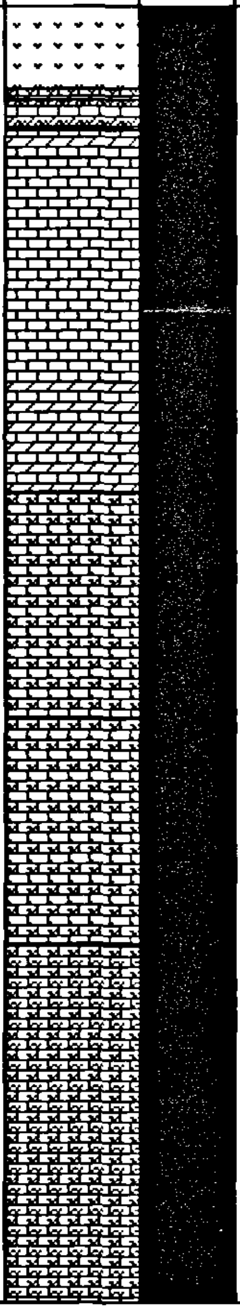
LITHOLOGICAL KEY:

- ANHYDRITE
- LIMESTONE
- MARLY LIMESTONE
- DOLOMITE

LATITUDE	35° 35' 42".57	DRILLING COMMENCED	25th. NOVEMBER 1955
LONGITUDE	44° 04' 22".38	DRILLING COMPLETED	28th. APRIL 1956
		TOTAL DEPTH	5288 FEET (1612 METRES)

AGE	FORMATION	DEPTH (ft)
EARLY TO MID MIOCENE	LOWER FARS Transition Beds.	4600
	EUPHRATES Lst.	
MID OLIGOCENE	BAJAWAN Lst.	4700
		4800
	BABA Lst.	4900
	TARJIL Fm.	5000
		5100
LATE OLIGOCENE	PALANI Fm.	

LITHOLOGICAL LOG



SAMPLE POINTS

SAMPLE Nos.

BH-8 / 1, BH-8 / 2, BH-8 / 3, BH-8 / 4, BH-8 / 5, BH-8 / 6, BH-8 / 7, BH-8 / 8, BH-8 / 9, BH-8 / 10, BH-8 / 11, BH-8 / 12, BH-8 / 13, BH-8 / 14, BH-8 / 15, BH-8 / 16, BH-8 / 17, BH-8 / 18, BH-8 / 19, BH-8 / 20, BH-8 / 21, BH-8 / 22, BH-8 / 23, BH-8 / 24, BH-8 / 25, BH-8 / 26, BH-8 / 27, BH-8 / 28, BH-8 / 29, BH-8 / 30, BH-8 / 31, BH-8 / 32, BH-8 / 33, BH-8 / 34, BH-8 / 35, BH-8 / 36, BH-8 / 37, BH-8 / 38, BH-8 / 39, BH-8 / 40, BH-8 / 41, BH-8 / 42, BH-8 / 43, BH-8 / 44, BH-8 / 45, BH-8 / 46, BH-8 / 47, BH-8 / 48, BH-8 / 49, BH-8 / 50, BH-8 / 51, BH-8 / 52, BH-8 / 53, BH-8 / 54, BH-8 / 55, BH-8 / 56

GEOLOGICAL DESCRIPTION

Brown, oily, very recrystallised, anhydritic, moluscan limestone.
Dolomite with a blue-grey marly limestone below.

White to cream, hard, dense, recrystallised back-reef imestone that contains occasional wisps of dense marl. The limestone also contains *Austrotrillina howchini*, *Archaias kirkukensis*, *Borelis pygmaea*, *Peneroplis evolutus*, *Rotalia viennoti*, small *Lepidocyclina* and occasional molluscan and coralline intervals.

Irregularly oily limestone with remnants of the back-reef and reef. Limestone contains *Borelis pygmaea*, small *Lepidocylina* sp. and coralline masses.

Brown, oil saturated, recrystallised, dolomitic reef limestone that contains *Actinacis* sp., *Rotalia viennoti*, rare *Borelis pygmaea*, small *Lepidocylina* sp. and *Heterostegina* sp..

Dolomitic, strongly recrystallised, porous, steeply fractured, oil soaked fore-reef limestone. The limestone contains *Rotalia viennoti*, small *Lepidocylina* sp., *Eulepidina* sp. and *Heterostegina* sp. below 4840 feet.

Brown, oil soaked marly limestone that becomes more marly and finer grained downwards. The marly limestone is from the fore-reef and contains large buliminids, small rotalids, *Globigerina* sp. and shell debris of *Lepidocyclina* sp., *Heterostegina* sp., *Eulephina* sp. and *Rotalia vienotti*.

Brown, oil soaked, very dense, marly limestone that contains globigerinids, bulliminids and shell debris of *Lepidocyclina* sp., *Heterostegina* sp., *Eulephina* sp. and *Rotalia vienotti*.

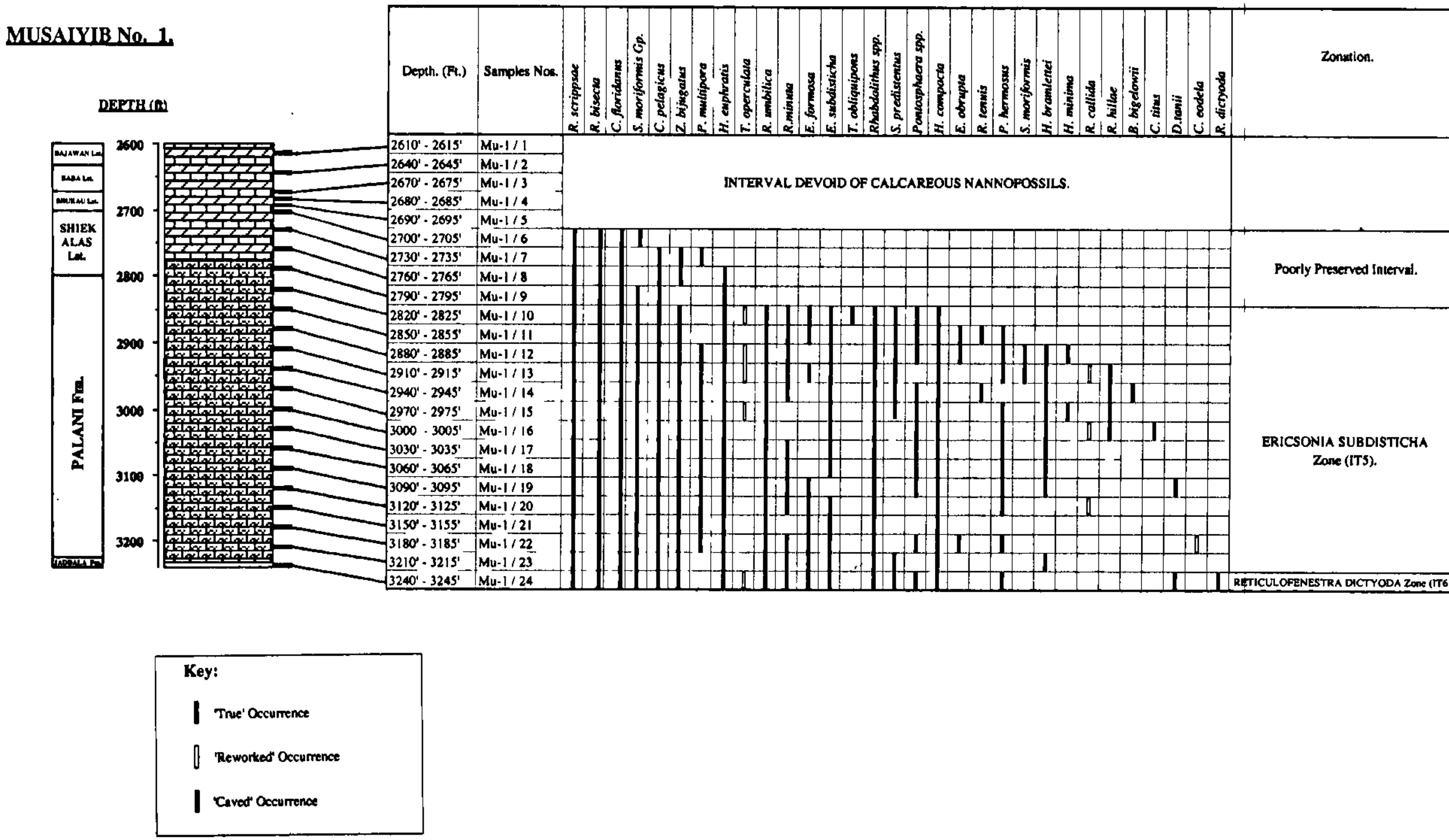
The marly limestone becomes more dense and banded, and the shell debris are less common and are locally concentrated. The marly limestone also contains a common pelagic fauna and becomes pyritic and glauconitic in nature below 5103 feet.

Fine, recrystallised, dense marl especially below 5183 feet. The marly limestone also contains scattered pyrite and glauconite, and possses a pelagic fauna and fine shell debris includining nummulite fragments (5239' - 5264').

MUSAIYIB No. 1.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

Range Chart.



MUSAIYIB No. 1.
DEPTH (ft)
2600
2700
2800
2900
3000
3100
3200
SHIEK ALAS Lst.
PALANI Fm.
Depth. (Ft.)
Samples Nos.
R. scrippsae
R. bisecta
C. floridanus
S. moriformis Gp.
C. pelagicus
Z. bijugatus
P. multipora
H. euphratis
T. operculata
R. umbilica
R. minuta
E. formosa
E. subdisticha
T. obliquipons
Rhabdolithus spp.
S. predistentus
Pontosphaera spp.
H. compacta
E. obruptu
R. tenuis
P. hermosus
S. moriformis
H. bramlettei
H. minima
R. callida
R. hillae
B. bigelowii
C. titus
D. tanii
C. eodela
R. dictyoda
Zonation.
2610' - 2615'
Mu-1 / 1
2640' - 2645'
Mu-1 / 2
2670' - 2675'
Mu-1 / 3
2680' - 2685'
Mu-1 / 4
2690' - 2695'
Mu-1 / 5
2700' - 2705'
Mu-1 / 6
2730' - 2735'
Mu-1 / 7
2760' - 2765'
Mu-1 / 8
2790' - 2795'
Mu-1 / 9
2820' - 2825'
Mu-1 / 10
2850' - 2855'
Mu-1 / 11
2880' - 2885'
Mu-1 / 12
2910' - 2915'
Mu-1 / 13
2940' - 2945'
Mu-1 / 14
2970' - 2975'
Mu-1 / 15
3000 - 3005'
Mu-1 / 16
3030' - 3035'
Mu-1 / 17
3060' - 3065'
Mu-1 / 18
3090' - 3095'
Mu-1 / 19
3120' - 3125'
Mu-1 / 20
3150' - 3155'
Mu-1 / 21
3180' - 3185'
Mu-1 / 22
3210' - 3215'
Mu-1 / 23
3240' - 3245'
Mu-1 / 24
INTERVAL DEVOID OF CALCAREOUS NANNOFOSSILS.
Poorly Preserved Interval.
ERICSONIA SUBDISTICHA Zone (IT5).
RETICULOFENESTRA DICTYODA Zone (IT6).
Key:
'True' Occurrence
'Reworked' Occurrence
'Caved' Occurrence

MUSAIYIB No. 1

LOCATION :

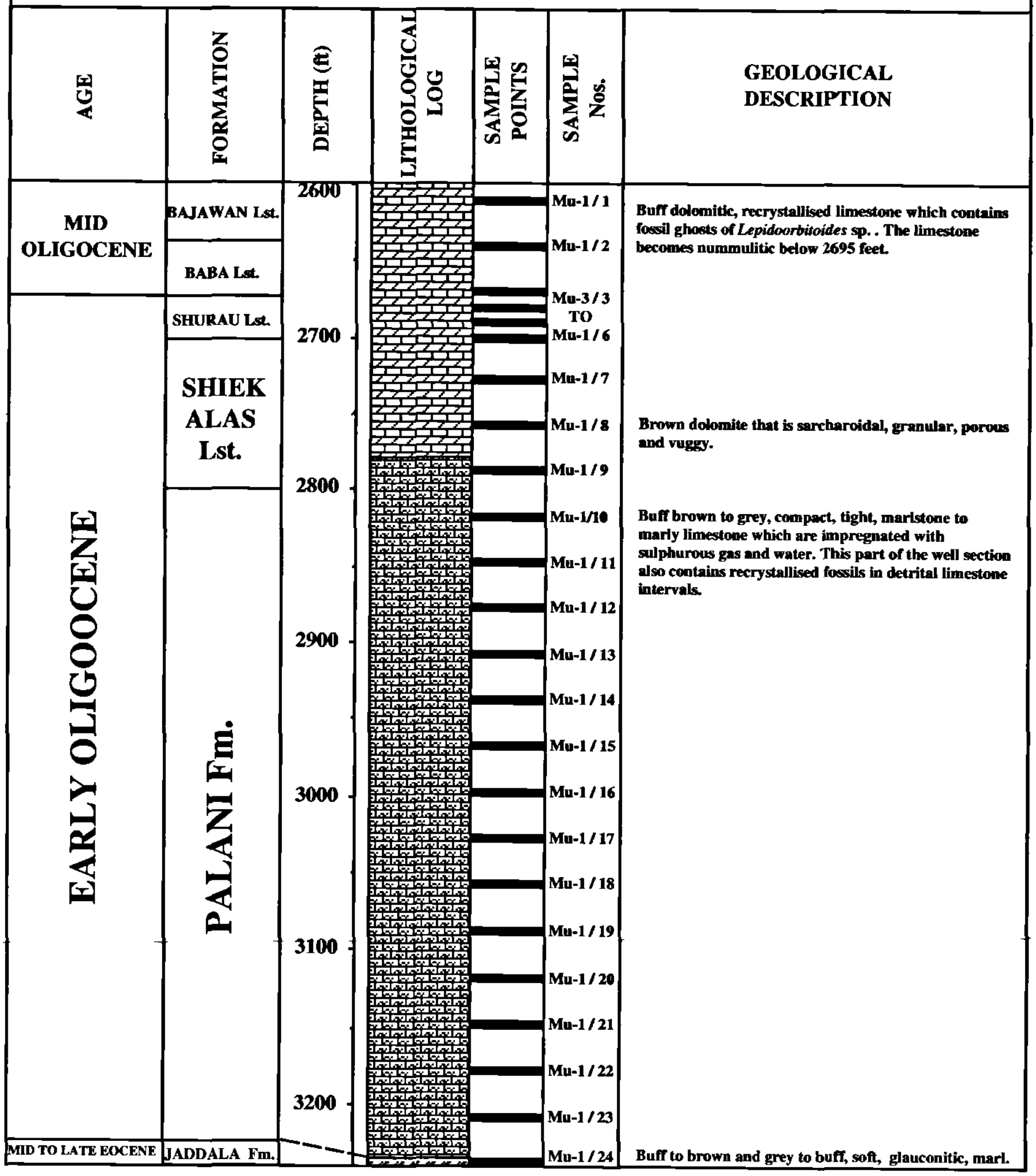
SOUTH OF BAGHDAD
CENTRAL IRAQ

EAST 1 445 000	
NORTH 1 201 000	

LITHOLOGICAL KEY:

- LIMESTONE
- MARLY LIMESTONES
- MARL
- DOLOMITE

DRILLING COMMENCED	3rd. DECEMBER 1957
DRILLING COMPLETED	NOT STATED
TOTAL DEPTH	NOT STATED



MUSAIYIB No. 1. Data Sheet.

Depth (Ft.)	Sample Nos.	*S. moriformis Gp.*	*R. scrippsae*	*R. bisecta*	*C. floridanus*	*C. pelagicus*	*Z. bijugatus*	*P. multipora*	*H. euphratis*	*T. operculata*	*R. umbilica*	*R. minuta*	*E. formosa*	*E. subdisticha*	*S. predistentus*	*T. obliquipons*	*Rhabdolithus spp.*	*Pontosphaera spp.*	*H. compacta*	*E. obrupta*	*R. tenuis*	*P. hermosus*	*S. moriformis*	*H. bramlettei*	*H. minima*	*R. callida*	*R. hillae*	*B. bigelowii*	*C. titus*	*D. tanii*	*C. eodela*	*R. dictyoda*	Total	Preservation State	No. Nannofossils per Field of View
2610' - 2615'	Mu-1 / 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	7.342
2640' - 2645'	Mu-1 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2670' - 2675'	Mu-1 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2680' - 2685'	Mu-1 / 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2690' - 2695'	Mu-1 / 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2700' - 2705'	Mu-1 / 6	3	2	15	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	2.5	0.013
2730' - 2735'	Mu-1 / 7	0	22	117	86	31	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	260	2.5	0.089
2760' - 2765'	Mu-1 / 8	0	80	105	86	26	10	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	310	2.5	0.108
2790' - 2795'	Mu-1 / 9	14	39	64	40	30	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	191	2.5	0.067
2820' - 2825'	Mu-1 / 10	10	16	107	111	24	2	0	1	2	1	2	1	6	4	2	7	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	306	1.5	8.941
2850' - 2855'	Mu-1 / 11	8	8	95	103	40	5	0	6	0	2	5	1	2	5	0	12	1	5	1	1	1	0	0	0	0	0	0	0	0	0	0	301	1.5	5
2880' - 2885'	Mu-1 / 12	9	34	50	87	52	4	3	18	1	12	4	0	3	2	0	22	3	15	1	0	3	3	3	2	0	0	0	0	0	0	0	331	1.5	11.033
2910' - 2915'	Mu-1 / 13	15	19	46	105	44	3	3	8	4	8	3	3	3	4	0	12	0	6	0	0	2	4	6	0	2	4	0	0	0	0	0	304	1.5	8.912
2940' - 2945'	Mu-1 / 14	12	24	23	119	30	12	6	23	0	2	1	0	3	5	0	25	4	4	0	1	0	0	4	0	0	1	1	0	0	0	0	300	1.5	9.677
2970' - 2975'	Mu-1 / 15	5	22	29	130	32	9	5	14	1	6	0	0	2	1	0	29	1	6	0	0	3	0	3	1	0	1	0	0	0	0	0	300	1.5	6.818
3000' - 3005'	Mu-1 / 16	9	28	32	154	24	10	4	4	0	2	0	0	3	0	0	17	2	10	0	0	2	0	3	0	2	1	0	2	0	0	0	309	1.5	7.326
3030' - 3035'	Mu-1 / 17	8	32	34	149	28	8	3	6	0	4	6	0	3	0	0	6	2	10	0	0	3	0	4	0	0	0	0	0	0	0	0	306	1.5	5.464
3060' - 3065'	Mu-1 / 18	7	32	31	161	19	2	4	7	0	4	12	0	1	0	0	12	2	5	0	0	4	0	1	0	0	0	0	0	0	0	0	304	1.5	5.067
3090' - 3095'	Mu-1 / 19	8	23	34	126	39	8	1	6	0	12	12	2	0	0	0	18	2	3	0	0	4	0	1	0	0	0	0	0	1	0	0	300	1.5	8.27
3120' - 3125'	Mu-1 / 20	7	32	23	103	67	4	4	5	0	12	7	1	5	0	0	27	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	302	1.5	6163
3150' - 3155'	Mu-1 / 21	10	24	18	153	69	5	1	4	0	3	0	1	8	0	0	11	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	309	1.5	11.036
3180' - 3185'	Mu-1 / 22	4	38	19	133	49	3	2	3	0	4	6	4	6	0	0	20	1	2	3	0	3	0	0	0	0	0	0	0	0	1	0	301	1.5	10.75
3210' - 3215'	Mu-1 / 23	10	32	34	132	52	5	0	1	0	5	3	4	6	2	0	22	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	311	1.5	18.412
3240' - 3245'	Mu-1 / 24	7	54	24	103	41	21	0	1	1	16	5	12	2	1	0	6	1	1	0	0	2	0	0	0	0	0	0	0	1	0	4	303	1.5	12.12

RACHI No. 1.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

RACHI No. 1

LOCATION:
NORTHWEST OF THE RUMAILA FIELD
SOUTHERN IRAQ

EAST 1 696 206 35
NORTH 917 338 63

LITHOLOGICAL KEY:

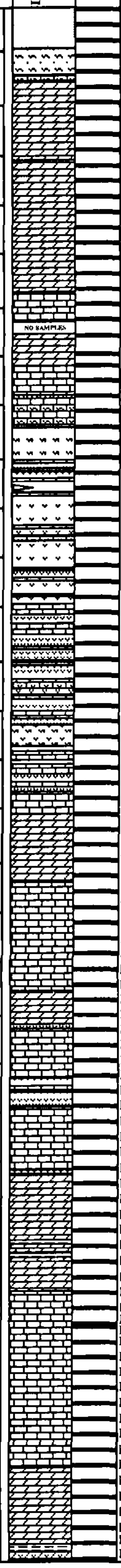
ANHYDRITE · LIMESTONE · MARLY LIMESTONE · DOLOMITE · SANDS · SHALE · MARLY

DRILLING COMMENCED	10th. JUNE 1956
DRILLING COMPLETED	NOT STATED
TOTAL DEPTH	NOT STATED

AGE	FORMATION
OLIGOCENE TO EARLY MIOCENE	ABU GHAR Fm.
MID EOCENE	DAMMAM Lst.
PALAEOCENE TO EARLY EOCENE	RUS ANHYDRITE
PALAEOCENE TO EARLY EOCENE	UMM ER RADHUMA Fm.
MAASTRICHTIAN	TAYARAT Fm.

DEPTH (ft): 1100, 1300, 1500, 1700, 1900, 2100, 2300, 2500, 2700, 2900, 3100, 3300, 3500, 3700, 3900

LITHOLOGICAL LOG



SAMPLE POINTS

SAMPLE Nos.: Ra-1/1 to Ra-1/102

GEOLOGICAL DESCRIPTION

Sand with no marly partings.

Sand with cream marly partings.

White arenaceous limestone underlain by white marl.

Light grey, pyritic, slightly arenaceous, recrystallised limestone becoming white, granular, recrystallised, friable and leached below 1060 feet

Nummulite casts.

Brown, sacharoidal dolomite with carbonaceous fragments and cavites. *Lockhartia* sp. occurs below 1515 feet.

Brown to buff, saccharoidal, vuggy, compact though locally porous dolomite and dolomitic limestone.

Greyish, friable marly limestone containing abundant nummulites passing into a greyish buff buff soft calcareous marl by 1741 feet.

Cream, marly, dolomitic limestone and marls.

Interbeded white anhydrite and limestones. The anhydrite is saccharoidal becoming porcellaneous below, with a poor platey fracture. The limestones are white, marly, recrystallised, friable and leached. They also contain abundant miliolids in some horizons.

Greyish anhydiritic marl.

Very fine grained, leached limestones with thin bitumen films. The limestones also contain miliolids and *Alveolina* sp..

Greyish limestone that is finely granular, slightly friable and marly in nature. The limestone also locally contains nodular and prismatic anhydrite and is dolomitic, passing into dolomite lower down. The limestones also contain abundant Textularids.

Same limestone as above but lacking dolomatisation.

Light grey, crystallise, granular, friable limestone with nodular anhydrite replacement and bituminous films near base.

Similar limestone as above except this limestone is greyish buff and locally dolomatized below 2870 feet. The limestone also has an algal layer at 2850 feet.

Buff, platy, fractured porcellanous anhydrite.

Grey, marly, leached, recrystallised limestone that becomes more compact downward.

Buff, platy, fractured porcellanous anhydrite.

Buff to cream, recrystallised limestone with nodular and prismatic anhydrite. The limestome becomes dark grey, strongly leached and contains Textularids towards the base.

Compact, granular to porcellaneous, vuggy, locally bituminous dolomites and dolomitic limestones.

Black, clayey, soft, bituminous shales with incipient dolomitisation.

Buff dolomite with a coarsely granular, non-uniform texture.

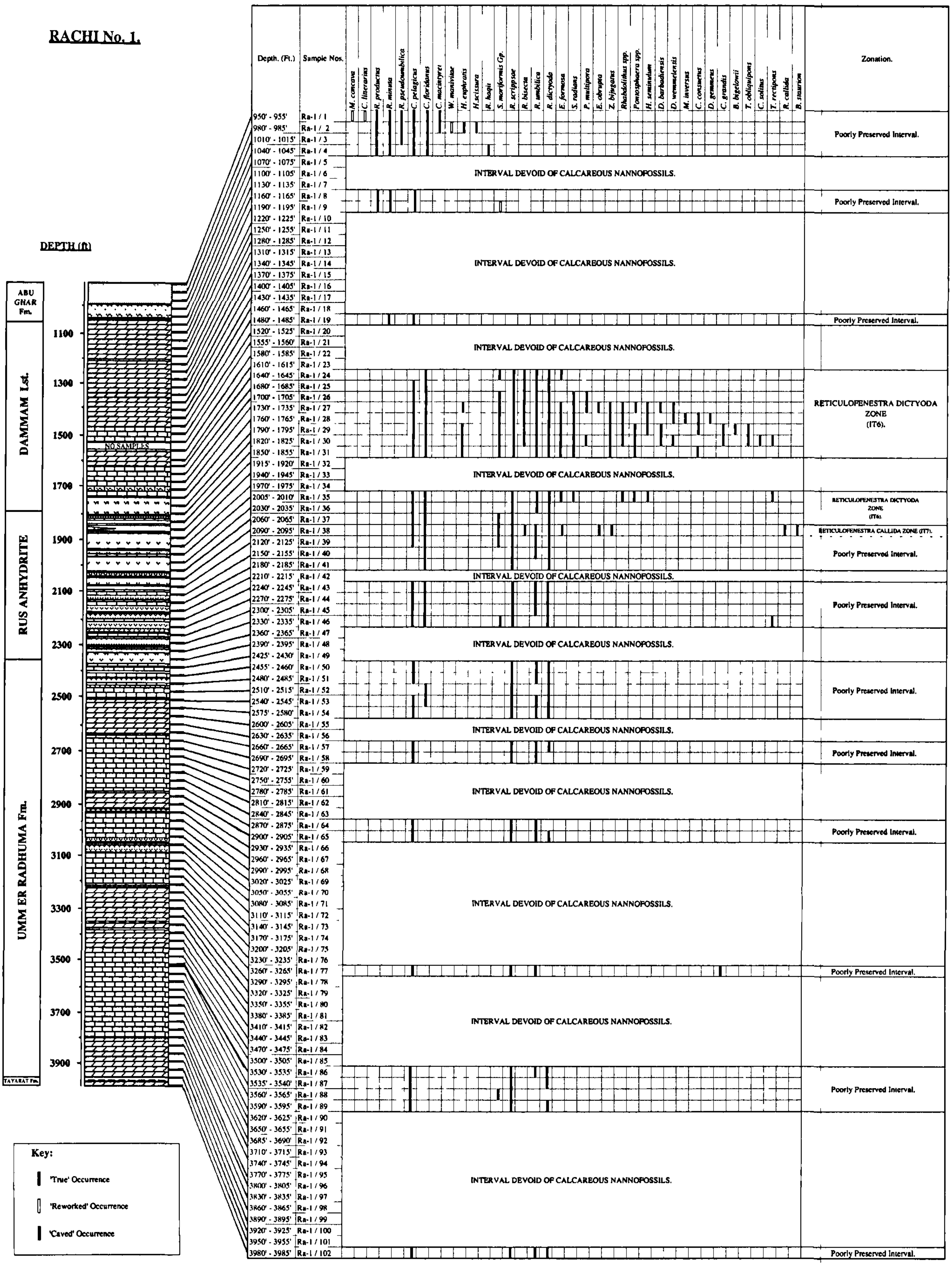
White, subporcellaneous limestones above 3498 feet, becoming becoming greyish white/ buff, granular and replaced by nodular anhydrite below. The limestone also becomes more compact towards the base

Buff, granular, slightly vuggy dolomites that contain scattered thin , black, bituminous marls.

Black, clayey, soft, bituminous shales which are incipiently dolomitised.

Depth (Ft.)	Sample Nos.	M. concava	C. litterarius	R. productus	R. minuta	R. pseudoumbilica	C. pelagicus	C. floridanus	C. macintyrei	W. manivitae	H. euphratis	H. scissura	R. haqii	S. moriformis Gp.	R. scrippsae	R. bisecta	R. umbilica	R. dictyoda	E. formosa	S. radians	P. multipora	E. obrupta	Z. bijugatus	Rhabdolithus spp.	Pontosphaera spp.	H. seminulum	D. barbadiensis	D. wemmelensis	M. inversus	C. consuetus	D. gemmeus	C. grandis	B. bigelowii	T. obliquipons	C. solitus	T. recipons	R. callida	B. staurion	Total.	Preservation State	No. Nannofossils per Field of View
950' - 955'	Ra-1 / 1	1	1	8	20	2	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	1.5	0.013
980' - 985'	Ra-1 / 2	0	0	44	27	4	9	9	1	2	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	1.5	0.035
1010' - 1015'	Ra-1 / 3	0	0	11	8	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	1.5	0.008
1040' - 1045'	Ra-1 / 4	0	0	9	9	0	3	5	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	2	0.01
1070' - 1075'	Ra-1 / 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1100' - 1105'	Ra-1 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1130' - 1135'	Ra-1 / 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1160' - 1165'	Ra-1 / 8	0	0	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1.5	0.002
1190' - 1195'	Ra-1 / 9	0	0	1	1	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	1.5	0.002
1220' - 1225'	Ra-1 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1250' - 1255'	Ra-1 / 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1280' - 1285'	Ra-1 / 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1310' - 1315'	Ra-1 / 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1340' - 1345'	Ra-1 / 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1370' - 1375'	Ra-1 / 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1400' - 1405'	Ra-1 / 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1430' - 1435'	Ra-1 / 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1460' - 1465'	Ra-1 / 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1480' - 1485'	Ra-1 / 19	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1.5	0.001
1520' - 1525'	Ra-1 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1555' - 1560'	Ra-1 / 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1580' - 1585'	Ra-1 / 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1610' - 1615'	Ra-1 / 23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1640' - 1645'	Ra-1 / 24	0	0	0	0	0	0	21	0	0	0	0	0	2	252	1	5	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	2	0.213
1680' - 1685'	Ra-1 / 25	0	0	0	0	0	1	38	0	0	0	0	0	0	235	2	6	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	2	6.522
1700' - 1705'	Ra-1 / 26	0	0	0	0	0	3	33	0	0	0	0	0	2	230	2	6	35	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	313	2	2.426
1730' - 1735'	Ra-1 / 27	0	0	0	0	0	23	20	0	0	2	0	0	5	216	5	5	8	2	3	1	1	2	6	2	8	1	4	0	0	0	0	0	0	0	0	0	0	314	2	1.472
1760' - 1765'	Ra-1 / 28	0	0	0	0	0	12	33	0	0	0	0	0	4	179	6	16	33	5	3	0	0	3	1	0	1	0	1	1	2	1	0	0	0	0	0	0	0	301	2	1.498
1790' - 1795'	Ra-1 / 29	0	0	0	0	0	22	24	0	0	3	0	0	9	124	2	43	28	17	2	0	0	1	1	2	3	4	0	0	4	0	4	7	2	0	0	0	0	302	2	0.2
1820' - 1825'	Ra-1 / 30	0	0	0	0	0	26	23	0	0	1	0	0	6	151	1	44	15	4	1	1	0	1	4	1	0	2	1	0	0	0	8	0	4	19	2	0	0	315	2	2.5
1850' - 1855'	Ra-1 / 31	0	0	0	0	0	12	36	0	0	2	0	0	12	172	0	22	26	2	2	0	0	6	0	4	0	0	0	0	4	0	0	0	0	0	0	0	0	300	2	0.144
1915' - 1920'	Ra-1 / 32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1940' - 1945'	Ra-1 / 33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1970' - 1975'	Ra-1 / 34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2005' - 2010'	Ra-1 / 35	0	0	0	0	0	16	26	0	0	0	0	0	0	134	0	43	38	14	3	0	0	0	6	6	3	0	0	0	0	0	0	0	0	0	8	0	0	297	2	0.104
2030' - 2035'	Ra-1 / 36	0	0	0	0	0	1	3	0	0	0	0	0	0	12	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	2	0.007
2060' - 2065'	Ra-1 / 37	0	0	0	0	0	2	3	0	0	0	0	0	1	8	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	2	0.006
2090' - 2095'	Ra-1 / 38	0	0	0	0	0	14	12	0	0	0	0	0	6	57	1	12	8	2	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	120	2	0.04
2120' - 2125'	Ra-1 / 39	0	0	0	0	0	1	1	0	0	0	0	0	1	8	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	2	0.005
2150' - 2155'	Ra-1 / 40	0	0	0	0	0	0	2	0	0	0	0	0	0	6	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	2	0.004
2180' - 2185'	Ra-1 / 41	0	0	0	0	0	0	1	0	0	0	0	0	0	6	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0.004
2210' - 2215'	Ra-1 / 42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2240' - 2245'	Ra-1 / 43	0	0	0	0	0	1	3	0	0	0	0	0	0	7	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	2	0.005
2270' - 2275'	Ra-1 / 44	0	0	0	0	0	1	1	0	0	0	0	0	0	6	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	2	0.004
2300' - 2305'	Ra-1 / 45	0	0	0	0	0	1	2	0	0	0	0	0	0	8	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	2	0.005
2330' - 2335'	Ra-1 / 46	0	0	0	0	0	1	2	0	0	0	0	0	1	9	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	17	2	0.006
2360' - 2365'	Ra-1 / 47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2390' - 2395'	Ra-1 / 48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2425' - 2430'	Ra-1 / 49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2455' - 2460'	Ra-1 / 50	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0.003
2480' - 2485'	Ra-1 / 51	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0.002
2510' - 2515'	Ra-1 / 52	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0.003
2540' - 2545'	Ra-1 / 53	0	0	0	0	0	2	1	0	0	0	0	0	0	2	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0.004
2575' - 2580'	Ra-1 / 54	0	0	0	0	0	1	0	0	0	0	0	0	0	4	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	2	0.003
2600' - 2605'	Ra-1 / 55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2630' - 2635'	Ra-1 / 56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2660' - 2665'	Ra-1 / 57	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0.002
2690' - 2695'	Ra-1 / 58	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0.002
2720' - 2725'	Ra-1 / 59	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2750' - 2755'	Ra-1 / 60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2780' - 2785'	Ra-1 / 61	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2810' - 2815'	Ra-1 / 62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2840' - 2845'	Ra-1 / 63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2870' - 2875'	Ra-1 / 64	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0.001
2900' - 2905'	Ra-1 / 65	0	0	0	0	0	2	0	0	0	0	0	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0.003
2930' - 2935'	Ra-1 / 66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2960' - 2965'	Ra-1 / 67	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
2990' - 2995'	Ra-1 / 68	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3020' - 3025'	Ra-1 / 69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3050' - 3055'	Ra-1 / 70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3080' - 3085'	Ra-1 / 71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3110' - 3115'	Ra-1 / 72	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3140' - 3145'	Ra-1 / 73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3170' - 3175'	Ra-1 / 74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3200' - 3205'	Ra-1 / 75	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3230' - 3235'	Ra-1 / 76	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3260' - 3265'	Ra-1 / 77	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	8	2	0.003
3290' - 3295'	Ra-1 / 78	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3320' - 3325'	Ra-1 / 79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3350' - 3355'	Ra-1 / 80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3380' - 3385'	Ra-1 / 81	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3410' - 3415'	Ra-1 / 82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3440' - 3445'	Ra-1 / 83	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3470' - 3475'	Ra-1 / 84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3500' - 3505'	Ra-1 / 85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3530' - 3535'	Ra-1 / 86	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0.002
3535' - 3540'	Ra-1 / 87	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0.002
3560' - 3565'	Ra-1 / 88	0	0	0	0	0	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0.002
3590' - 3595'	Ra-1 / 89	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0.001
3620' - 3625'	Ra-1 / 90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3650' - 3655'	Ra-1 / 91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3685' - 3690'	Ra-1 / 92	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3710' - 3715'	Ra-1 / 93	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3740' - 3745'	Ra-1 / 94	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3770' - 3775'	Ra-1 / 95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3800' - 3805'	Ra-1 / 96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3830' - 3835'	Ra-1 / 97	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3860' - 3865'	Ra-1 / 98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3890' - 3895'	Ra-1 / 99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3920' - 3925'	Ra-1 / 100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3950' - 3955'	Ra-1 / 101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
3980' - 3985'	Ra-1 / 102	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0.002

Range Chart


RACHI No. 1.
DEPTH (ft)
ABU GHAR Fm.
DAMMAM Lst.
RUS ANHYDRITE
UMM ER RADHUMA Fm.
TAYARAT Fm.
1100
1300
1500
1700
1900
2100
2300
2500
2700
2900
3100
3300
3500
3700
3900
NO SAMPLES
Depth. (Ft.)
Sample Nos.
M. concava
C. litterarius
R. productus
R. minuta
R. pseudoumbilica
C. pelagicus
C. floridanus
C. macintyrei
W. moniviae
H. euphratis
H. scissura
R. haqii
S. moriformis Gp.
R. scrippsae
R. bisecta
R. umbilica
R. dictyoda
E. formosa
S. radians
P. multipora
E. obrupta
Z. bijugatus
Rhabdolithus spp.
Pontosphaera spp.
H. seminulum
D. barbadiensis
D. wemmelensis
M. inversus
C. consuetus
D. gemmeus
C. grandis
B. bigelowii
T. obliquipons
C. solitus
T. recitpons
R. callida
B. staurion
Zonation.
950' - 955' Ra-1 / 1
980' - 985' Ra-1 / 2
1010' - 1015' Ra-1 / 3
1040' - 1045' Ra-1 / 4
1070' - 1075' Ra-1 / 5
1100' - 1105' Ra-1 / 6
1130' - 1135' Ra-1 / 7
1160' - 1165' Ra-1 / 8
1190' - 1195' Ra-1 / 9
1220' - 1225' Ra-1 / 10
1250' - 1255' Ra-1 / 11
1280' - 1285' Ra-1 / 12
1310' - 1315' Ra-1 / 13
1340' - 1345' Ra-1 / 14
1370' - 1375' Ra-1 / 15
1400' - 1405' Ra-1 / 16
1430' - 1435' Ra-1 / 17
1460' - 1465' Ra-1 / 18
1480' - 1485' Ra-1 / 19
1520' - 1525' Ra-1 / 20
1555' - 1560' Ra-1 / 21
1580' - 1585' Ra-1 / 22
1610' - 1615' Ra-1 / 23
1640' - 1645' Ra-1 / 24
1680' - 1685' Ra-1 / 25
1700' - 1705' Ra-1 / 26
1730' - 1735' Ra-1 / 27
1760' - 1765' Ra-1 / 28
1790' - 1795' Ra-1 / 29
1820' - 1825' Ra-1 / 30
1850' - 1855' Ra-1 / 31
1915' - 1920' Ra-1 / 32
1940' - 1945' Ra-1 / 33
1970' - 1975' Ra-1 / 34
2005' - 2010' Ra-1 / 35
2030' - 2035' Ra-1 / 36
2060' - 2065' Ra-1 / 37
2090' - 2095' Ra-1 / 38
2120' - 2125' Ra-1 / 39
2150' - 2155' Ra-1 / 40
2180' - 2185' Ra-1 / 41
2210' - 2215' Ra-1 / 42
2240' - 2245' Ra-1 / 43
2270' - 2275' Ra-1 / 44
2300' - 2305' Ra-1 / 45
2330' - 2335' Ra-1 / 46
2360' - 2365' Ra-1 / 47
2390' - 2395' Ra-1 / 48
2425' - 2430' Ra-1 / 49
2455' - 2460' Ra-1 / 50
2480' - 2485' Ra-1 / 51
2510' - 2515' Ra-1 / 52
2540' - 2545' Ra-1 / 53
2575' - 2580' Ra-1 / 54
2600' - 2605' Ra-1 / 55
2630' - 2635' Ra-1 / 56
2660' - 2665' Ra-1 / 57
2690' - 2695' Ra-1 / 58
2720' - 2725' Ra-1 / 59
2750' - 2755' Ra-1 / 60
2780' - 2785' Ra-1 / 61
2810' - 2815' Ra-1 / 62
2840' - 2845' Ra-1 / 63
2870' - 2875' Ra-1 / 64
2900' - 2905' Ra-1 / 65
2930' - 2935' Ra-1 / 66
2960' - 2965' Ra-1 / 67
2990' - 2995' Ra-1 / 68
3020' - 3025' Ra-1 / 69
3050' - 3055' Ra-1 / 70
3080' - 3085' Ra-1 / 71
3110' - 3115' Ra-1 / 72
3140' - 3145' Ra-1 / 73
3170' - 3175' Ra-1 / 74
3200' - 3205' Ra-1 / 75
3230' - 3235' Ra-1 / 76
3260' - 3265' Ra-1 / 77
3290' - 3295' Ra-1 / 78
3320' - 3325' Ra-1 / 79
3350' - 3355' Ra-1 / 80
3380' - 3385' Ra-1 / 81
3410' - 3415' Ra-1 / 82
3440' - 3445' Ra-1 / 83
3470' - 3475' Ra-1 / 84
3500' - 3505' Ra-1 / 85
3530' - 3535' Ra-1 / 86
3535' - 3540' Ra-1 / 87
3560' - 3565' Ra-1 / 88
3590' - 3595' Ra-1 / 89
3620' - 3625' Ra-1 / 90
3650' - 3655' Ra-1 / 91
3685' - 3690' Ra-1 / 92
3710' - 3715' Ra-1 / 93
3740' - 3745' Ra-1 / 94
3770' - 3775' Ra-1 / 95
3800' - 3805' Ra-1 / 96
3830' - 3835' Ra-1 / 97
3860' - 3865' Ra-1 / 98
3890' - 3895' Ra-1 / 99
3920' - 3925' Ra-1 / 100
3950' - 3955' Ra-1 / 101
3980' - 3985' Ra-1 / 102
Poorly Preserved Interval.
INTERVAL DEVOID OF CALCAREOUS NANNOFOSSILS.
RETICULOFENESTRA DICTYODA ZONE (IT6).
RETICULOFENESTRA DICTYODA ZONE (IT6).
RETICULOFENESTRA CALLIDA ZONE (IT7).
Key:
'True' Occurrence
'Reworked' Occurrence
'Caved' Occurrence

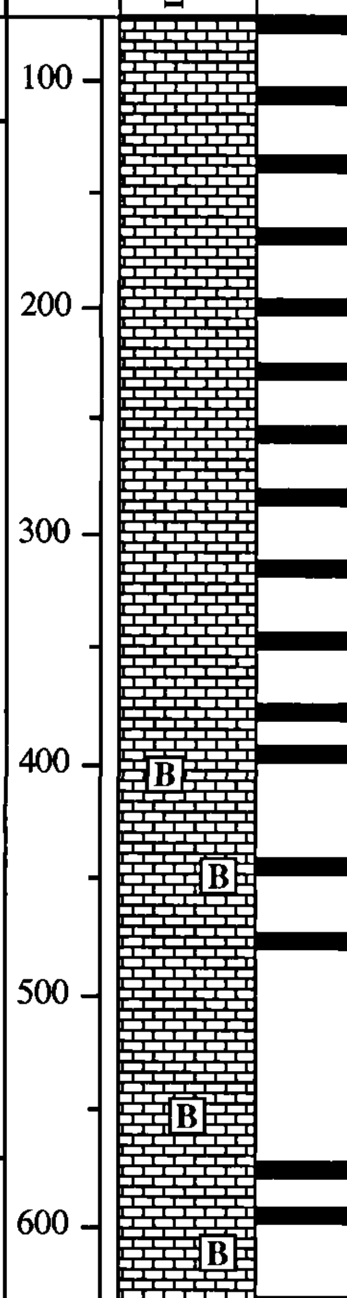
ATSHAN No. 1

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

ATSHAN No. 1

LOCATION :	LITHOLOGICAL KEY:
ATSHAN FIELD NORTHERN IRAQ	LIMESTONE; B BITUMINOUS LAYERS

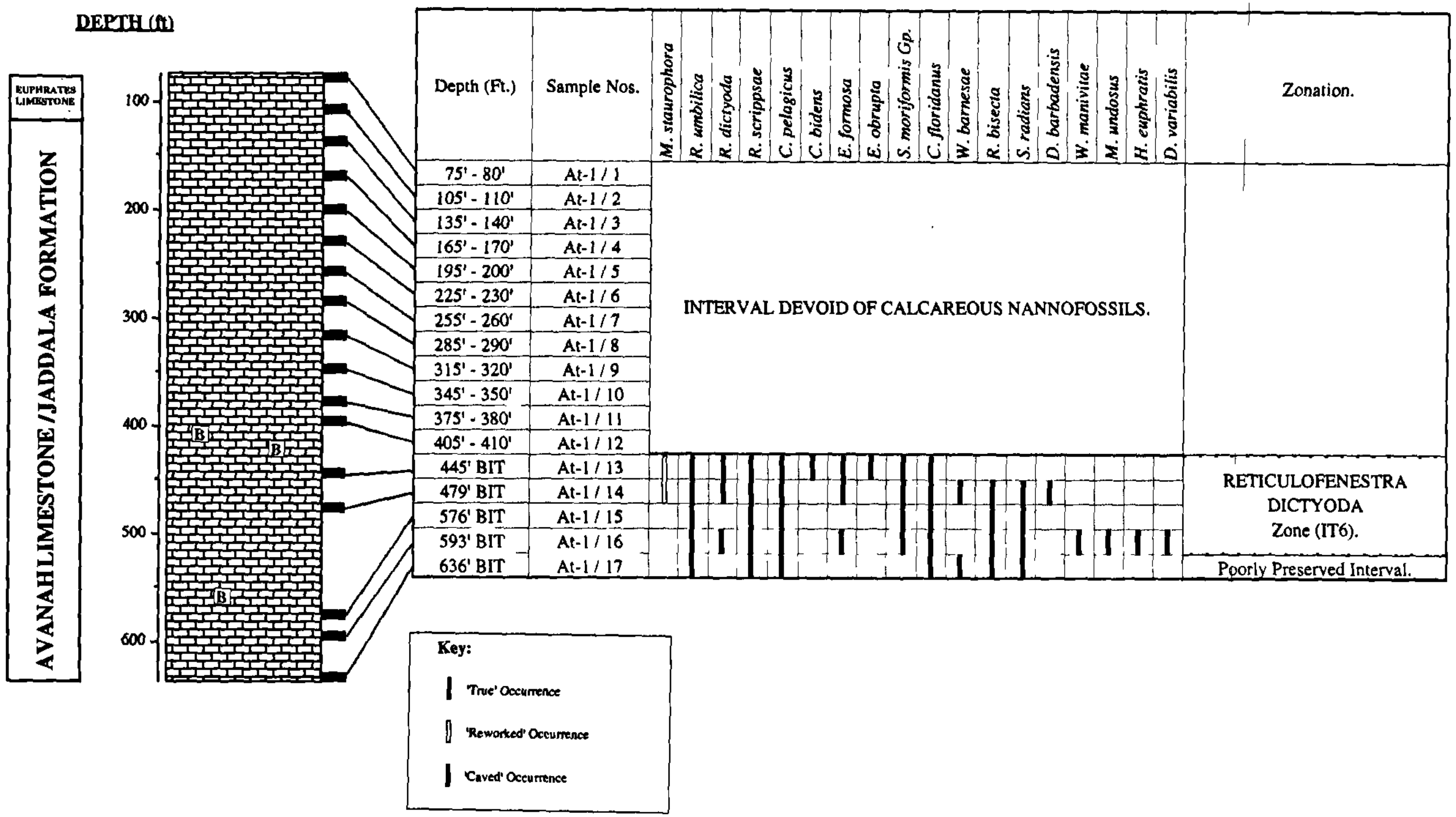
East 19 68.5	DRILLING COMMENCED	25th. MARCH 1954
North 32 71 64	DRILLING COMPLETED	NOT STATED
	TOTAL DEPTH	NOT STATED



AGE	FORMATION	DEPTH (ft)	SAMPLE Nos.	GEOLOGICAL DESCRIPTION
EARLY MIOCENE	EUPHRATES LIMESTONE	100	At-1 / 1, At-1 / 2	Shelly, white or grey tinged limestones, which are fine-grained, marly, hardish, slightly porous and vuggy. They are also tight, brittle, and slightly cherty at 97'-103' and 107'-115'.
MID TO LATE EOCENE	AVANAH LIMESTONE / JADDALA FORMATION		At-1 / 3, At-1 / 4, At-1 / 5	Bluish-white, fine-grained, finely crystalline, hard tight limestone.
		200	At-1 / 6, At-1 / 7, At-1 / 8, At-1 / 9, At-1 / 10	Greyish-white, very fine grained, fairly marly limestones, next to tight, bluish-white porous and vuggy nummulitic limestone.
		300–400	At-1 / 11, At-1 / 12	Bluish-grey to greyish-white, brittle nummulitic limestones interbedded with greyish- white, fine-grained limestones.
			At-1 / 13, At-1 / 14	Pale grey-white to brownish-grey and brownish-grey limestones, all of which are fine-grained, some exhibiting slickensides.
		500		Locally detrital pale-grey limestones, which are fine-grained, slightly shaly, soft and tight with abundant microfauna.
PALAEOCENE TO EARLY EOCENE	KHURMALA LIMESTONE / AALIJI FORMATION	600	At-1 / 15, At-1 / 16, At-1 / 17	Pale grey, fine-grained, marly, and tight limestones, intergrading and interbedded with arenaceous-detrital beds of sandy limestone which are, grey white, locally pourous, with detrital calcite, quartz and pyrite grains, some microfauna present.

Range Chart

ATSHAN No. 1



ATSHAN No.1 Data Sheet

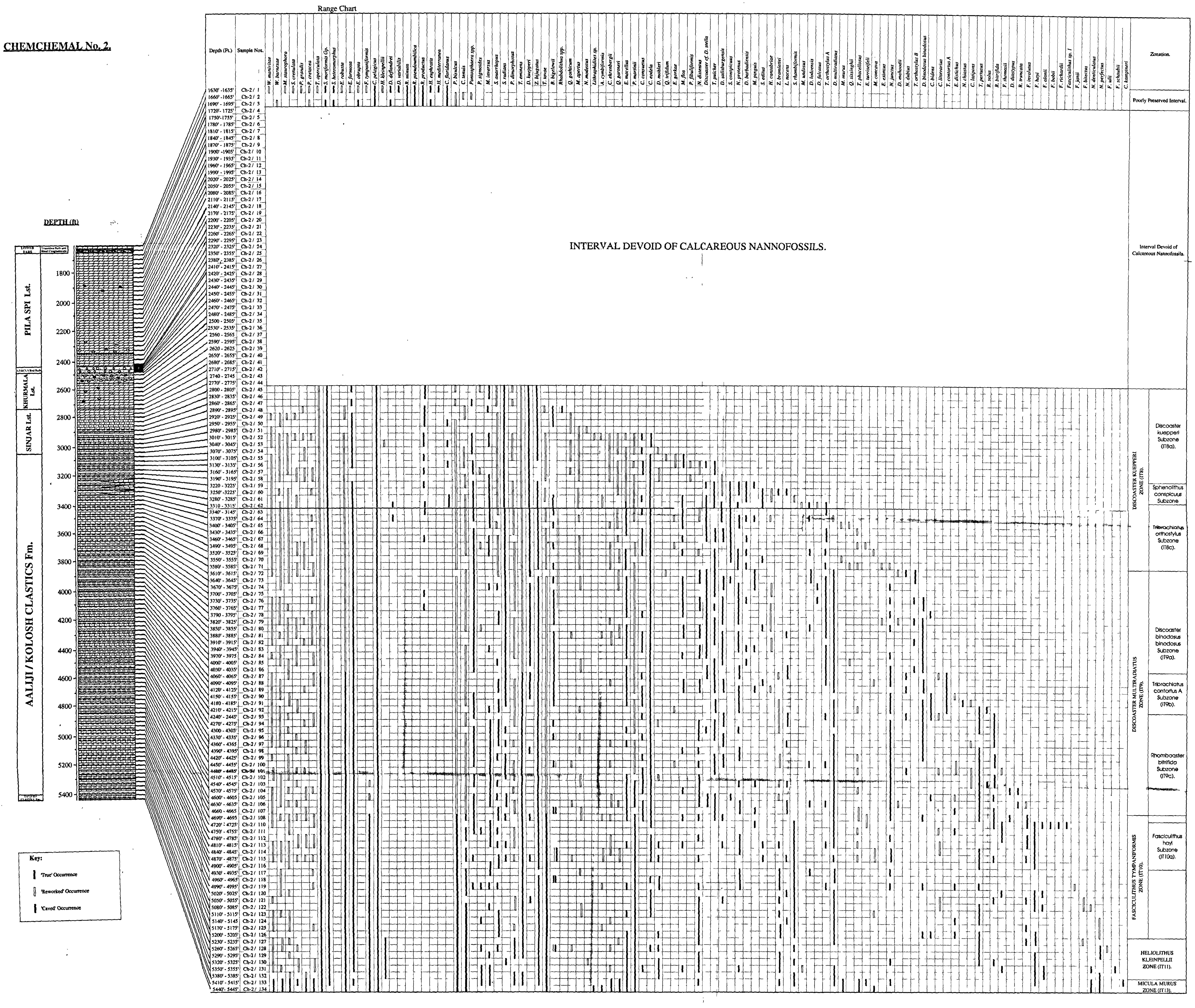
Depth (Ft.)	Sample Nos.	*M. staurophora*	*R. umbilica*	*R. dictyoda*	*R. scrippsae*	*C. pelagicus*	*C. bidens*	*E. formosa*	*E. obrupta*	*S. moriformis Gp.*	*C. floridanus*	*W. barnesae*	*R. bisecta*	*S. radians*	*D. barbadensis*	*W. manivitae*	*M. undosus*	*H. euphratis*	*D. variabilis*	Total	Preservation State	No. Nannofossils per Field of View
75' - 80'	At-1 / 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
105' - 110'	At-1 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
135' - 140'	At-1 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
165' - 170'	At-1 / 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
195' - 200'	At-1 / 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
225' - 230'	At-1 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
255' - 260'	At-1 / 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
285' - 290'	At-1 / 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
315' - 320'	At-1 / 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
345' - 350'	At-1 / 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
375' - 380'	At-1 / 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
405' - 410'	At-1 / 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
445' BIT	At-1 / 13	2	8	1	7	7	1	1	1	7	2	0	0	0	0	0	0	0	0	37	2.0	0
479' BIT	At-1 / 14	2	30	1	4	17	0	1	0	15	4	1	2	1	1	0	0	0	0	54	2.0	0.047
576' BIT	At-1 / 15	0	2	0	3	2	0	0	0	2	1	0	1	1	0	0	0	0	0	12	2.0	0.004
593' BIT	At-1 / 16	0	35	2	39	3	0	1	0	6	1	0	3	1	0	1	1	1	1	95	2.0	0.033
636' BIT	At-1 / 17	0	2	0	5	1	0	0	0	0	1	1	1	1	0	0	0	0	0	12	2.0	0.004
1460' - 1465'	At-1 / 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
1490' - 1495'	At-1 / 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0

CHEMCHEMAL No. 2.

KEY:	
Abundance Rating	No. of Nannofossils per Field of View
Very Low	< 1.0
Low	1-10
Moderate	> 10-20
High	>20-30
Very High	+30

Preservation State	Description
E-3	Highly Etched
E-2	Moderately Etched
E-1	Slightly Etched
X	Excellent
O-1	Slightly Overgrown
O-2	Moderately Overgrown
O-3	Heavily Overgrown

CHEMCHEMAL No. 2.



Depth (Ft.)	Sample Nos.	Total	Preservation	No. of Nannofossils per Field of View
1630'-1635'	Ch-2/1	314	1.5	0.242
1660'-1665'	Ch-2/1	15	1.5	0.006
1690'-1695'	Ch-2/3	110	1.5	0.4
1720'-1725'	Ch-2/4	0	-	0
1750'-1755'	Ch-2/5	0	-	0
1780'-1785'	Ch-2/6	0	-	0
1810'-1815'	Ch-2/7	0	-	0
1840'-1845'	Ch-2/8	0	-	0
1870'-1875'	Ch-2/9	0	-	0
1900'-1905'	Ch-2/10	0	-	0
1930'-1935'	Ch-2/11	0	-	0
1960'-1965'	Ch-2/12	0	-	0
1990'-1995'	Ch-2/13	0	-	0
2020'-2025'	Ch-2/14	0	-	0
2050'-2055'	Ch-2/15	0	-	0
2080'-2085'	Ch-2/16	0	-	0
2110'-2115'	Ch-2/17	0	-	0
2140'-2145'	Ch-2/18	0	-	0
2170'-2175'	Ch-2/19	0	-	0
2200'-2205'	Ch-2/20	0	-	0
2230'-2235'	Ch-2/21	0	-	0
2260'-2265'	Ch-2/22	0	-	0
2290'-2295'	Ch-2/23	0	-	0
2320'-2325'	Ch-2/24	0	-	0
2350'-2355'	Ch-2/25	0	-	0
2380'-2385'	Ch-2/26	0	-	0
2410'-2415'	Ch-2/27	0	-	0
2420'-2425'	Ch-2/28	0	-	0
2430'-2435'	Ch-2/29	0	-	0
2440'-2445'	Ch-2/30	0	-	0
2450'-2455'	Ch-2/31	0	-	0
2460'-2465'	Ch-2/32	0	-	0
2470'-2475'	Ch-2/33	0	-	0
2480'-2485'	Ch-2/34	0	-	0
2500'-2505'	Ch-2/35	0	-	0
2530'-2535'	Ch-2/36	0	-	0
2560'-2565'	Ch-2/37	0	-	0
2590'-2595'	Ch-2/38	0	-	0
2620'-2625'	Ch-2/39	0	-	0
2650'-2655'	Ch-2/40	0	-	0
2680'-2685'	Ch-2/41	0	-	0
2710'-2715'	Ch-2/42	0	-	0
2740'-2745'	Ch-2/43	0	-	0
2770'-2775'	Ch-2/44	0	-	0
2800'-2805'	Ch-2/45	58	1.5	0.002
2830'-2835'	Ch-2/46	26	1.5	0.01
2860'-2865'	Ch-2/47	96	2	0.033
2890'-2895'	Ch-2/48	64	1.5	0.022
2920'-2925'	Ch-2/49	65	1.5	0.022
2950'-2955'	Ch-2/50	92	1.5	0.031
2980'-2985'	Ch-2/51	90	1.5	0.032
3010'-3015'	Ch-2/52	330	1.5	0.924
3040'-3045'	Ch-2/53	300	1.5	0.361
3070'-3075'	Ch-2/54	300	1.5	0.227
3100'-3105'	Ch-2/55	315	1.5	0.115
3130'-3135'	Ch-2/56	308	1.5	0.395
3160'-3165'	Ch-2/57	301	1.5	0.993
3190'-3195'	Ch-2/58	312	1.5	0.396
3220'-3225'	Ch-2/59	300	1.5	0.385
3250'-3255'	Ch-2/60	307	1.5	1.066
3280'-3285'	Ch-2/61	305	1.5	1.066
3310'-3315'	Ch-2/62	301	1.5	1.027
3340'-3345'	Ch-2/63	300	1.5	1.038
3370'-3375'	Ch-2/64	304	1.5	1.075
3400'-3405'	Ch-2/65	300	1.5	1.083
3430'-3435'	Ch-2/66	102	1.5	0.036
3460'-3465'	Ch-2/67	179	1.5	0.063
3490'-3495'	Ch-2/68	308	1.5	0.395
3520'-3525'	Ch-2/69	316	1.5	0.111
3550'-3555'	Ch-2/70	128	1.5	0.045
3580'-3585'	Ch-2/71	300	1.5	0.105
3610'-3615'	Ch-2/72	159	1.5	0.056
3640'-3645'	Ch-2/73	313	1.5	1.204
3670'-3675'	Ch-2/74	303	1.5	1.165
3700'-3705'	Ch-2/75	300	1.5	1.154
3730'-3735'	Ch-2/76	302	1.5	0.581
3760'-3765'	Ch-2/77	304	1.5	0.105
3790'-3795'	Ch-2/78	313	1.5	0.602
3820'-3825'	Ch-2/79	300	1.5	0.769
3850'-3855'	Ch-2/80	312	1.5	1.2
3880'-3885'	Ch-2/81	300	1.5	1.154
3910'-3915'	Ch-2/82	303	1.5	1.165
3940'-3945'	Ch-2/83	307	1.5	4.708
3970'-3975'	Ch-2/84	301	1.5	3.846
4000'-4005'	Ch-2/85	303	1.5	2.904
4030'-4035'	Ch-2/86	307	1.5	2.84
4060'-4065'	Ch-2/87	309	1.5	2.748
4090'-4095'	Ch-2/88	303	1.5	1.072
4120'-4125'	Ch-2/89	309	1.5	1.674
4150'-4155'	Ch-2/90	303	1.5	1.938
4180'-4185'	Ch-2/91	314	1.5	2.853
4210'-4215'	Ch-2/92	312	1.5	2.289
4240'-4245'	Ch-2/93	323	1.5	1.346
4270'-4275'	Ch-2/94	304	1.5	3.577
4300'-4305'	Ch-2/95	301	1.5	3.541
4330'-4335'	Ch-2/96	301	1.5	1.942
4360'-4365'	Ch-2/97	321	1.5	1.134
4390'-4395'	Ch-2/98	300	1.5	1.167
4420'-4425'	Ch-2/99	316	1.5	2.273
4450'-4455'	Ch-2/100	306	1.5	7.846
4480'-4485'	Ch-2/101	300	1.5	2.027
4510'-4515'	Ch-2/102	314	1	6.826
4540'-4545'	Ch-2/103	300	1	4.286
4570'-4575'	Ch-2/104	302	1	3.432
4600'-4605'	Ch-2/105	300	1	2.479
4630'-4635'	Ch-2/106	318	1	1.036
4660'-4665'	Ch-2/107	306	1	7.116
4690'-4695'	Ch-2/108	304	1.5	0.863
4720'-4725'	Ch-2/109	301	1.5	4.778
4750'-4755'	Ch-2/110	303	1.5	7.214
4780'-4785'	Ch-2/111	310	1.5	14.091
4810'-4815'	Ch-2/112	308	1.5	1.446
4840'-4845'	Ch-2/113	304	1.5	2.905
4870'-4875'	Ch-2/114	308	1.5	3.157
4900'-4905'	Ch-2/115	302	0.5	16.778
4930'-4935'	Ch-2/116	300	1	4.918
4960'-4965'	Ch-2/117	307	1	12.28
4990'-4995'	Ch-2/118	300	1	4.631
5020'-5025'	Ch-2/119	313	1	5.691
5050'-5055'	Ch-2/120	300	1	10
5080'-5085'	Ch-2/121	301	1	5.017
5110'-5115'	Ch-2/122	302	1	4.254
5140'-5145'	Ch-2/123	300	1	3.529
5170'-5175'	Ch-2/124	303	1	5.05
5200'-5205'	Ch-2/125	300	1	6.04
5230'-5235'	Ch-2/126	300	1	6.383
5260'-5265'	Ch-2/127	300	1	8.333
5290'-5295'	Ch-2/128	302	1	12
5320'-5325'	Ch-2/129	301	1	10.033
5350'-5355'	Ch-2/130	300	1	8.108
5380'-5385'	Ch-2/131	300	1	13.043
5410'-5415'	Ch-2/132	316	1.5	1.892
5440'-5445'	Ch-2/133	300	1.5	6

CHEMCHEMAL No. 2

LOCATION : EAST OF KIRKUK, NORTHERN IRAQ

LITHOLOGICAL KEY:

LIMESTONE · MARLY LIMESTONE · DETRITAL LIMESTONE · SHALE · MARL · ANHYDRITE · CONGLOMERATE · BITUMINOUS LAYERS · CHERT NODULES/ INCLUSIONS · ANHYDRITE NODULES/ INCLUSIONS

LATITUDE		DRILLING COMMENCED	NOT STATED
LONGITUDE		DRILLING COMPLETED	NOT STATED
		TOTAL DEPTH	NOT STATED

AGE	FORMATION	DEPTH (ft)	SAMPLE Nos.	GEOLOGICAL DESCRIPTION
MID MIOCENE	LOWER FARS (Transition Beds and Basal Conglomerate)		Ch-2/1 – Ch-2/3	Interbedded anhydrites and limestones. The basal limestone of the Transition Beds (T-13 limestone) is sampled. Conglomerate composed of pebbles of chert, white recrystallised limestone and a grey recrystallised limestone similar to those of the Lower Fars Formation.
PALAEOCENE TO EARLY EOCENE	PILA SPI Lst.	1800, 2000, 2200, 2400	Ch-2/4 – Ch-2/27	White to brown, strongly recrystallised, dolomitic limestone which has occasional chert inclusions towards the top (1880 feet to 1926 feet). The limestone also contains anhydite iclusions which increase in number from 2060 feet to 2365 feet, where thin bedded anhydrites occur. The limestone is also porous and vuggy and has some vertical fracture surfaces, bitumen and native sulphur also occurs sporadically through the limestone. A number of bethonic foaminifers have been retrieved from the limestone including *Peneroplis dusenburyi*, *Peneroplis* cf. *damesini*, abundant *Praerhapydionina huberi*, *Rhipidionina* sp ?., *Coskinolina* sp., miliolids, small rotalids, textularids and large verneulinids.
	GERCUS Red Beds		TO	Anhydritic, red indurated marl with two conglomerate bedscomposed of red marl, anhydrite, and pebbles of a hard, sandy limestone, chert and radiolarite.
	KHURMALA Lst.	2600	Ch-2/34 – Ch-2/43	Completely recrystallised, dolomitic limestone with anhydrite and chert inclusions, streaks of green marl and bitumen staining between 2480 feet and 2554 feet. Ther limestone becomes more porous lower down and contains anhydite nodules.
	SINJAR Lst.	2800, 3000	Ch-2/44 – Ch-2/53	Dolomitic and recrystallised limestone that contains an abundant nummulite fauna. The limestones become less dolomitic upto 2800 feet, and contain a fore-reef fauna. In addition from 2894 feet to the base of the formation, nummulitic detrital limestones are interbedded with soft blue and brown marls and shales. The numulitic fauna from 2735 feet to 3000 feet includes *Alveolina* spp., *A. elliptica*, *Nummulites discorbinus*, *N. atacicus*, *N. globulus*, *N. lucasanus* v. *carpathica*, *N. fraasi*, *Assilina placentula*, *Operculina salsa*, *O. herberti*, *Orbitolites complanata*, *Daviesina ghilizarda*, *Lafittaina* sp., *Rotalia trocidiformis*, *Echinorotalia* and *Discocyclina* sp. .
	AALIJI / KOLOSH CLASTICS Fm.	3200, 3400, 3600, 3800, 4000, 4200, 4400, 4600, 4800, 5000, 5200	Ch-2/54 – Ch-2/131	Tongues of Sinjar Limestone Formation. Grey calcareous mudstones, often banded and mottled brown, interbedded with thin argillaceous and marly limestones, marls, silts and detrital limestones. This interbeded sequence only shows rare occurences of *Globigerina* sp. to 3600 feet but, below this depth *Globigerina* sp. is abundant. In addition below 4100 feet *Globorotalia velascoensis*, *Globorotalia* sp. and *Gumbelina* sp. have been recorded.
MAASTRICHTIAN	TANJERO CLASTICS Fm.	5400	Ch-2/132 – Ch-2/133	Similar lithologies to the Aaliji / Kolosh Clastics Formations above but is differentiated by the occurrence of *Globotruncana* spp.

LITHOLOGICAL LOG

SAMPLE POINTS

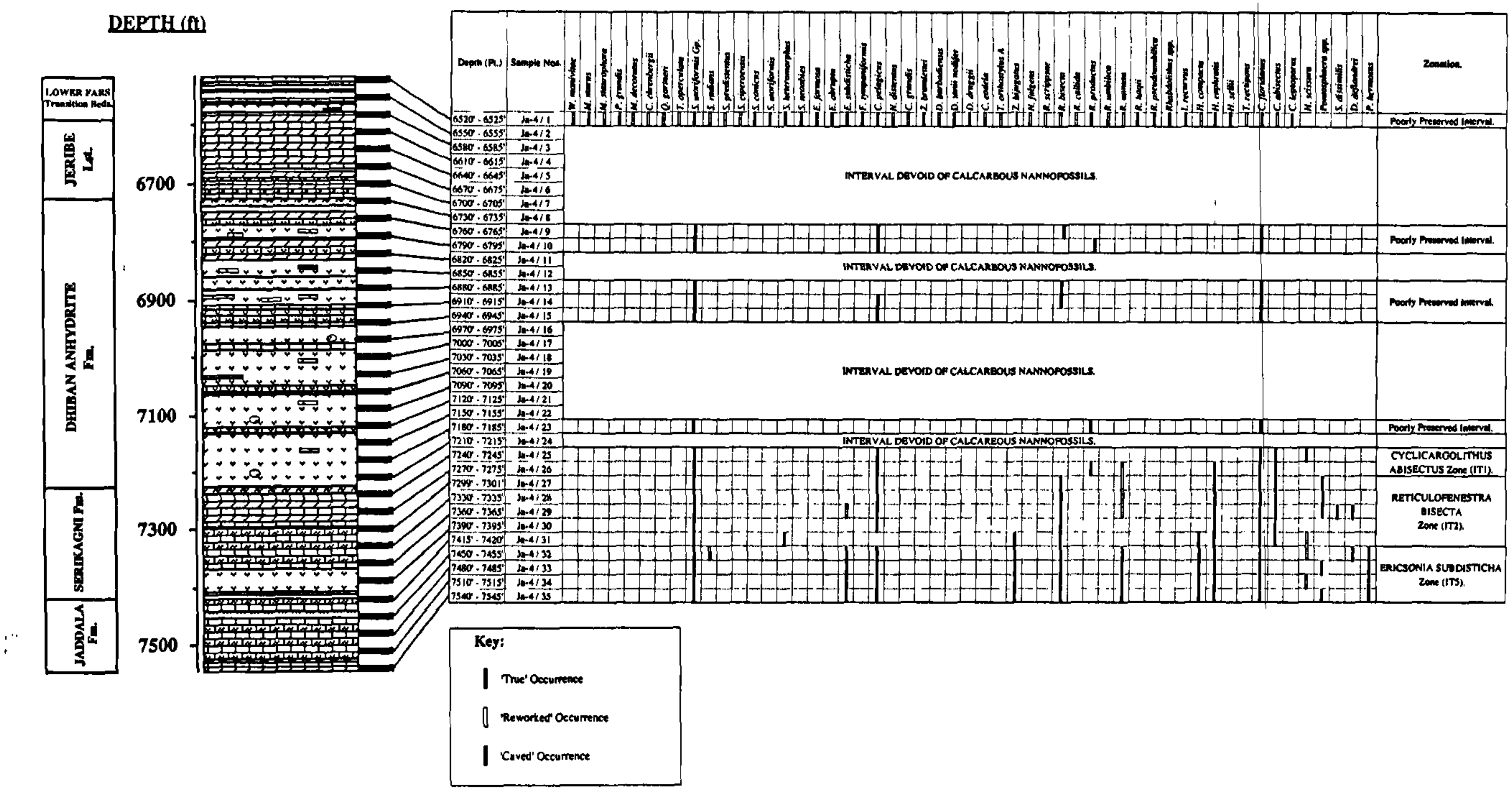
SAMPLE Nos.: Ch-2/1, Ch-2/2, Ch-2/3, Ch-2/4, Ch-2/5, Ch-2/6, Ch-2/7, Ch-2/8, Ch-2/9, Ch-2/10, Ch-2/11, Ch-2/12, Ch-2/13, Ch-2/14, Ch-2/15, Ch-2/16, Ch-2/17, Ch-2/18, Ch-2/19, Ch-2/20, Ch-2/21, Ch-2/22, Ch-2/23, Ch-2/24, Ch-2/25, Ch-2/26, Ch-2/27, TO, Ch-2/34, Ch-2/35, Ch-2/36, Ch-2/37, Ch-2/38, Ch-2/39, Ch-2/40, Ch-2/41, Ch-2/42, Ch-2/43, Ch-2/44, Ch-2/45, Ch-2/46, Ch-2/47, Ch-2/48, Ch-2/49, Ch-2/50, Ch-2/51, Ch-2/52, Ch-2/53, Ch-2/54, Ch-2/55, Ch-2/56, Ch-2/57, Ch-2/58, Ch-2/59, Ch-2/60, Ch-2/61, Ch-2/62, Ch-2/63, Ch-2/64, Ch-2/65, Ch-2/66, Ch-2/67, Ch-2/68, Ch-2/69, Ch-2/70, Ch-2/71, Ch-2/72, Ch-2/73, Ch-2/74, Ch-2/75, Ch-2/76, Ch-2/77, Ch-2/78, Ch-2/79, Ch-2/80, Ch-2/81, Ch-2/82, Ch-2/83, Ch-2/84, Ch-2/85, Ch-2/86, Ch-2/87, Ch-2/88, Ch-2/89, Ch-2/90, Ch-2/91, Ch-2/92, Ch-2/93, Ch-2/94, Ch-2/95, Ch-2/96, Ch-2/97, Ch-2/98, Ch-2/99, Ch-2/100, Ch-2/101, Ch-2/102, Ch-2/103, Ch-2/104, Ch-2/105, Ch-2/106, Ch-2/107, Ch-2/108, Ch-2/109, Ch-2/110, Ch-2/111, Ch-2/112, Ch-2/113, Ch-2/114, Ch-2/115, Ch-2/116, Ch-2/117, Ch-2/118, Ch-2/119, Ch-2/120, Ch-2/121, Ch-2/122, Ch-2/123, Ch-2/124, Ch-2/125, Ch-2/126, Ch-2/127, Ch-2/128, Ch-2/129, Ch-2/130, Ch-2/131, Ch-2/132, Ch-2/133

JAMBUR No. 4.

KEY:		Preservation State	Description
Abundance Rating	No. of Nannofossils per Field of View	E-3	Highly Etched
Very Low	< 1.0	E-2	Moderately Etched
Low	1-10	E-1	Slightly Etched
Moderate	> 10-20	X	Excellent
High	>20-30	O-1	Slightly Overgrown
Very High	+30	O-2	Moderately Overgrown
		O-3	Heavily Overgrown

Range Chart

JAMBUR No. 4.



JAMBUR No. 4. Data Sheet.

Depth (Ft.)	Sample Nos.	W. manivitae	M. murus	M. staurophora	P. grandis	M. decoratus	C. ehrenbergii	Q. garneri	T. operculata	S. moriformis Gp.	S. radians	S. predistentus	S. ciperoensis	S. conicus	S. dissimilis	S. moriformis	S. heteromorphus	S. neoabies	E. formosa	E. obrupta	E. subdisticha	F. tympaniformis	C. pelagicus	N. distentus	C. grandis	Z. bramletei	D. barbadiensis	D. tanii nodifer	D. deflandrei	D. druggii	C. eodela	T. orthostylus A	Z. bijugatus	N. fulgens	R. scrippsae	R. bisecta	R. callida	R. productus	R. umbilica	R. minuta	R. hagii	R. pseudoumbilica	Rhabdolithus spp.	Pontosphaera spp.	I. recurvus	H. compacta	H. euphratis	H. scissura	H. sellii	T. recipons	C. floridanus	C. abisectus	C. leptoporus	P. hermosus	Total	Preservation State	No. Nannofossils per Field of View
6520' - 6525'	Ja-4 / 1	2	1	1	1	1	1	1	1	12	2	1	3	1	0	2	3	3	2	2	1	1	48	1	1	1	1	1	0	2	1	1	3	1	2	5	2	24	3	7	3	3	1	0	1	1	5	0	2	1	132	5	2	0	302	1	7.342
6550' - 6555'	Ja-4 / 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6580' - 6585'	Ja-4 / 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6610' - 6615'	Ja-4 / 4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6640' - 6645'	Ja-4 / 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6670' - 6675'	Ja-4 / 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6700' - 6705'	Ja-4 / 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6730' - 6735'	Ja-4 / 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6760' - 6765'	Ja-4 / 9	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	59	1	0.021
6790' - 6795'	Ja-4 / 10	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	11	2	0.004
6820' - 6825'	Ja-4 / 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6850' - 6855'	Ja-4 / 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
6880' - 6885'	Ja-4 / 13	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	8	2	0.003
6910' - 6915'	Ja-4 / 14	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	10	2	0.004
6940' - 6945'	Ja-4 / 15	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	7	2	0.003
6970' - 6975'	Ja-4 / 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7000' - 7005'	Ja-4 / 17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7030' - 7035'	Ja-4 / 18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7060' - 7065'	Ja-4 / 19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7090' - 7095'	Ja-4 / 20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7120' - 7125'	Ja-4 / 21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7150' - 7155'	Ja-4 / 22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7180' - 7185'	Ja-4 / 23	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	8	2	0.003
7210' - 7215'	Ja-4 / 24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0
7240' - 7245'	Ja-4 / 25	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	4	2	0	0	27	2	0.01
7270' - 7275'	Ja-4 / 26	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	45	0	0	0	0	0	0	3	0	0	0	183	2	0	0	302	2.5	1.659
7299' - 7301'	Ja-4 / 27	0	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0	5	0	0	0	1	0	0	2	0	0	0	222	2	0	0	310	2.5	4.7
7330' - 7335'	Ja-4 / 28	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	6	0	0	0	2	0	0	5	0	0	0	211	2	0	0	303	2	4.97
7360' - 7365'	Ja-4 / 29	0	0	0	0	0	0	0	0	45	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	33	0	0	0	8	0	0	0	4	0	0	11	0	0	0	198	2	0	0	305	2	5.351
7390' - 7395'	Ja-4 / 30	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	3	0	0	47	2.5	0.016
7415' - 7420'	Ja-4 / 31	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	2	3	6	0	0	30	6	0	0	74	2	0.026
7450' - 7455'	Ja-4 / 32	0	0	0	0	0	0	0	0	36	1	0	0	0	0	0	0	0	0	0	2	0	19	0	0	0	0	0	2	0	0	0	1	0	2	59	0	0	0	5	0	0	0	0	0	4	1	1	0	0	176	0	0	1	309	2.5	5
7480' - 7485'	Ja-4 / 33	0	0	0	0	0	0	0	0	38	0	0	0	0	0	0	0	0	0	0	9	0	22	0	0	0	0	0	0	0	0	0	2	0	8	89	0	0	0	2	0	0	0	1	0	2	1	0	0	0	127	0	0	1	301	2.5	6.565
7510' - 7515'	Ja-4 / 34	0	0	0	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	0	3	0	24	0	0	0	0	0	0	0	0	0	2	0	3	57	0	0	0	3	0	0	0	0	0	4	4	1	0	0	133	0	0	2	305	2.5	5.482
7540' - 7545'	Ja-4 / 35	0	0	0	0	0	0	0	0	73	0	0	0	0	0	0	0	0	0	0	4	0	23	0	0	0	0	0	0	0	0	0	2	0	8	59	0	0	0	3	0	0	0	1	0	3	3	0	0	0	139	0	0	1	318	2	6.38

JAMBUR No. 4

LOCATION :

JAMBUR FIELD
NORTHERN IRAQ

LATITUDE	35° 07' 35".63
LONGITUDE	44° 35' 17".03

DRILLING COMMENCED	1st. NOVEMBER 1954
DRILLING COMPLETED	11th. SEPTEMBER 1955
TOTAL DEPTH	7739 FEET (2322 METRES)

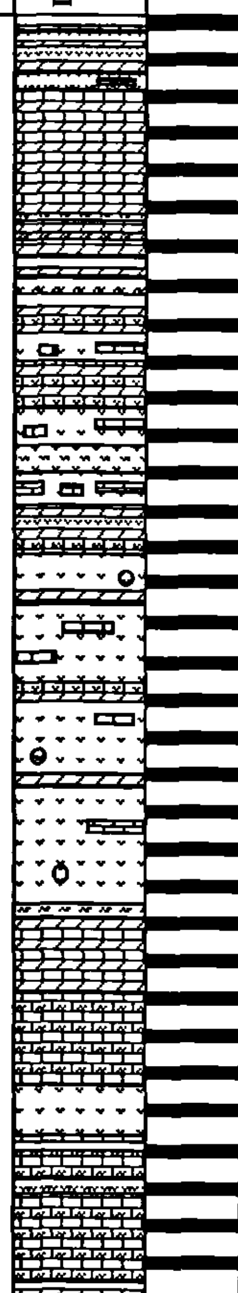
LITHOLOGICAL KEY:

ANHYDRITE	LIMESTONE
MARLY LIMESTONES	MARLY NODULES
DOLOMITE	ANHYDRITE NODULES
MARL	LIMESTONE INCLUSIONS

AGE	FORMATION
LATE MIOCENE	LOWER FARS Transition Beds.
LATE MIOCENE	JERIBE Lst.
EARLY TO MID MIOCENE	DHIBAN ANHYDRITE Fm.
EARLY MIOCENE	SERIKAGNI Fm.
MID TO LATE EOCENE	JADDALA Fm.

DEPTH (ft): 6700, 6900, 7100, 7300, 7500

LITHOLOGICAL LOG / SAMPLE POINTS



SAMPLE Nos.: Ja-4 / 1, Ja-4 / 2, Ja-4 / 3, Ja-4 / 4, Ja-4 / 5, Ja-4 / 6, Ja-4 / 7, Ja-4 / 8, Ja-4 / 9, Ja-4 / 10, Ja-4 / 11, Ja-4 / 12, Ja-4 / 13, Ja-4 / 14, Ja-4 / 15, Ja-4 / 16, Ja-4 / 17, Ja-4 / 18, Ja-4 / 19, Ja-4 / 20, Ja-4 / 21, Ja-4 / 22, Ja-4 / 23, Ja-4 / 24, Ja-4 / 25, Ja-4 / 26, Ja-4 / 27, Ja-4 / 28, Ja-4 / 29, Ja-4 / 30, Ja-4 / 31, Ja-4 / 32, Ja-4 / 33, Ja-4 / 34, Ja-4 / 35

GEOLOGICAL DESCRIPTION

Fawn anhydritic, dolomitic limestone with abundant gastropods.
Grey, very marly, silty and pyritic limestone.
Fawn-grey to grey, marly, flocculitic limestone with scattered silt and anhydrite inclusions.

Light fawn, marly, dolomitic limestone with scattered silt, wisps of pyrite, interstitual anhydrite and veinlets of anhydrite.

Dark blue limey marl.
Grey, marly, somewhat dolomitic limestone with vague shell debris.
The base of this limestone has an oil stained dark blue silty marl.
Fawn, marly, dolomitic limestone with silt and wisps of pyrite, interbedded with anhydrite bands. the limestone also contains chilostomellids, and echinoid and mollusc debris.
Rare limy pockets
Fawn, marly dolomitic limestones which are anhyditic in the upper part and are oil stained. The limestone are also silty in parts and contain molluscs, echinoids and *Miogypsina* sp.
Anydite with abundant limestone inclusions in the middle part.
Blue-grey marl and anhydrite with a fawn-grey, marly, dolomitic limestone above which contains molluscs, echinoids, miliolids, chilostomellids and bryzoa.
White anhydrite with limestone inclusions with a fawn, marly dolomitic limestone at its base.
Grey, silicified,silty, sandy dolomite with pyrite bloches.
Brown, oil stained, marly, vaguely sub-oolitic dolomite with interstitual anhydrite and recrystallised fossils.
Fawn, marly, dolomite with some oil staining and interstitual pyrite.
The dolomite also contains molluscs, miliolids, chilostomellids and *Omphalocyclus* sp.
White anhydrite with brown tint at top and abundant fawn limestone at 7030'-35'. Fawn limestone intergrows with the anhydrite below.

White anhydrite with rare pockets of fawn limestone and green-grey marl.
Fawn limestone that is marly, dolomitic and very anhydritic in nature.

Dull white anhydrite with grey tints and occasional inclusions of grey limestone and blue-grey marl.
Fawn, limey marl with globigerinids, gumbelinids and some miliolids.

Fawn to brown, marly, dolomitic limestone with tary oil impregnations and interstitual anhydrite. The limestone also contains miliolids, molluscs, echinoids, algal fragments and globigerinids.
Fawn, marly, occasionally dolomitic, limestone with scattered silt and pyrite. The limestone also contain globigerinids, gumbelinids, mililolids, *Miogypsina* sp., echinoids, molluscs and algae.
White anhydrite with limey inclusions.

Generally light grey to dark blue, occasionally fawn, marly limestone. The marly limestone can be both anhydritic and dolomitic and contains globigerinids, gumbelinids, milolids, *Cibicides* sp., *Hanthenina* sp., echinoids, molluscs, ostracods, algae and bryozoan debris.

KEY: Abundance Rating	No. of Nannofossils per Field of View	Preservation State	Description
Very Low	< 1.0	E-3	Highly Etched
Low	1-10	E-2	Moderately Etched
Moderate	> 10-20	E-1	Slightly Etched
High	>20-30	X	Excellent
Very High	+30	O-1	Slightly Overgrown
		O-2	Moderately Overgrown
		O-3	Heavily Overgrown

PULKHANA No. 5

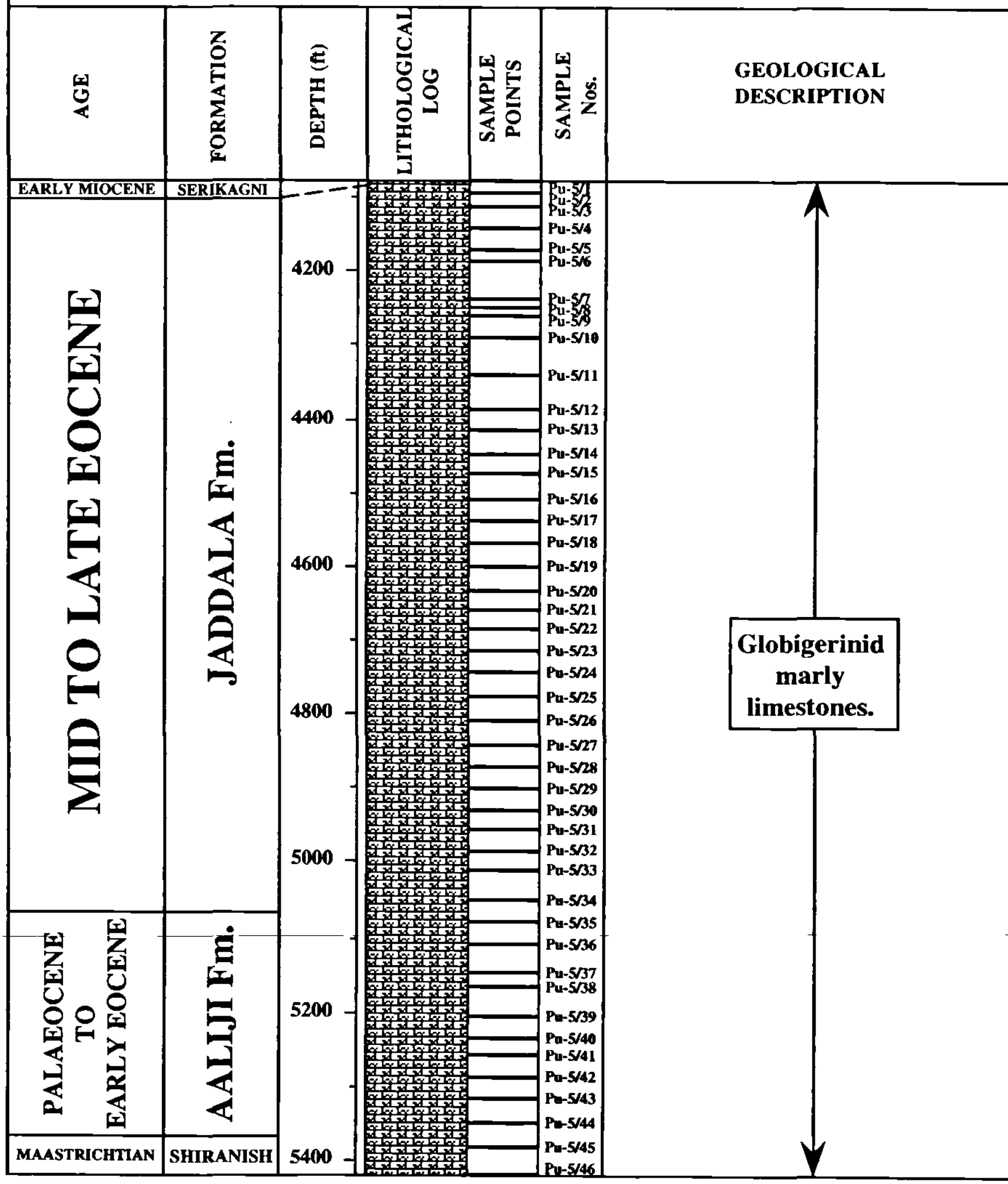
LOCATION :
SOUTHEAST OF THE
JAMBUR FIELD
NORTHERN IRAQ

LATITUDE	34° 47' 58".80 N
LONGITUDE	44° 46' 58".80 E

LITHOLOGICAL KEY:

MARLY LIMESTONE

DRILLING COMMENCED	NOT STATED
DRILLING COMPLETED	NOT STATED
TOTAL DEPTH	NOT STATED



Pulkhana No. 5.

Data Sheet.

Depth (Ft.)	Sample Nos.	S. moriformis Gp.	S. dissimilis	C. pelagicus	D. deflandrei	B. bigelowii	Z. bijugatus	R. scrippsae	R. bisecta	Pontosphaera spp.	H. compacta	H. euphratis	H. kamptneri	C. floridanus	C. abisectus	T. operculata	S. radians	E. obruptus	E. subdisticha	P. multipora
4075' - 4080'	Pu-5/1	21	12	15	6	3	23	7	15	3	3	3	3	24	164	0	0	0	0	0
Core No. 21 4085' - 4095'	Pu-5/2	18	0	13	0	0	1	0	160	8	18	18	0	33	0	2	1	4	24	8
Core No. 22 4107' - 4112'	Pu-5/3	47	0	14	0	0	0	3	118	1	4	14	0	92	0	0	0	0	6	0
Core No. 24 4137' - 4139'	Pu-5/4	32	0	18	0	0	2	11	89	1	5	26	0	126	0	0	0	0	7	0
Core No. 27 4169' - 4174'	Pu-5/5	60	0	24	0	0	3	6	23	0	3	1	0	154	0	0	0	3	20	0
Core No. 27 4179' - 4183'	Pu-5/6	38	0	41	0	0	2	18	63	1	3	6	0	98	0	0	3	0	18	0
Core No. 31 4239' - 4244.5'	Pu-5/7	57	0	43	6	0	2	24	26	0	3	5	0	112	0	0	1	4	16	0
Core No. 32 4255' - 4260'	Pu-5/8	37	0	40	1	0	2	22	43	1	3	8	0	124	0	0	0	2	17	2
Core No. 32 4285' - 4288'	Pu-5/9	51	0	33	0	0	2	14	64	1	7	5	0	104	0	0	0	3	12	0
Core No. 34 4323' - 4328'	Pu-5/10	57	0	29	0	0	0	10	39	2	4	5	0	122	0	0	1	4	12	2
Core No. 35 4334' - 4339'	Pu-5/11	79	0	49	4	0	3	7	36	1	2	5	0	92	0	0	1	0	21	0
Core No. 36 4379' - 4384'	Pu-5/12	34	0	41	0	2	10	28	37	0	1	8	0	107	0	0	1	4	16	0
Core No. 36 4409' - 4414'	Pu-5/13	38	0	45	0	1	8	16	44	0	2	9	0	106	0	0	0	4	14	0
Core No. 37 4441' - 4446'	Pu-5/14	19	0	45	0	0	3	71	75	1	6	0	0	65	0	0	0	3	0	0
Core No. 38 4471' - 4476'	Pu-5/15	29	0	60	0	0	11	70	75	0	2	0	0	42	0	0	0	4	0	0
Core No. 39 4502' - 4507'	Pu-5/16	52	0	53	0	0	9	35	107	0	5	0	0	26	0	0	3	3	0	0
Core No. 39 4532' - 4537'	Pu-5/17	91	0	41	0	0	14	60	46	0	4	0	0	24	0	0	7	1	0	0
Core No. 40 4562' - 4567'	Pu-5/18	75	0	36	0	0	16	66	60	0	5	0	0	25	0	0	4	0	0	0
Core No. 41 4592' - 4597'	Pu-5/19	10	0	40	0	0	9	74	28	0	10	0	0	14	0	0	25	1	0	0
Core No. 41 4622' - 4627'	Pu-5/20	29	0	42	0	0	10	49	32	0	9	0	0	38	0	0	18	0	0	0
Core No. 42 4652' - 4657'	Pu-5/21	6	0	38	0	0	4	74	36	0	0	0	0	7	0	0	19	0	0	0
Core No. 43 4678' - 4683'	Pu-5/22	10	0	67	0	0	0	63	12	2	15	0	0	30	0	0	16	3	0	0
Core No. 43 4708' - 4713'	Pu-5/23	6	0	81	0	0	0	43	28	2	15	0	0	15	0	0	7	4	0	0
Core No. 44 4738' - 4743'	Pu-5/24	18	0	78	0	0	0	42	10	0	6	0	0	18	0	0	14	2	0	0
4770' 4775'	Pu-5/25	12	0	50	0	0	2	45	40	2	9	0	0	35	0	0	7	2	2	0
Core No. 46 4800' - 4805'	Pu-5/26	15	0	55	0	2	7	70	0	0	0	0	0	26	0	0	28	0	0	0
Core No. 46 4835' 4840'	Pu-5/27	3	0	75	0	0	4	85	0	0	0	0	0	35	0	0	4	6	0	0
Core No. 47 4860' - 4865'	Pu-5/28	7	0	69	0	0	9	107	0	0	0	0	0	55	0	0	10	2	0	0
Core No. 47 4890' - 4895'	Pu-5/29	3	0	46	0	0	4	181	0	0	0	0	0	31	0	0	9	0	0	0
Core No. 48 4920' - 4925'	Pu-5/30	3	0	67	0	0	6	123	0	1	0	0	0	45	0	0	15	0	0	0
Core No. 49 4950' - 4955'	Pu-5/31	6	0	37	0	0	12	175	0	0	0	0	0	35	0	0	9	0	0	0
Core No. 49 4980' - 4985'	Pu-5/32	5	0	16	0	0	19	84	0	0	0	0	0	84	0	1	11	0	0	0
Core No. 50 5010' - 5015'	Pu-5/33	3	0	39	0	0	17	42	0	0	0	0	0	57	0	0	8	0	0	0
Core No. 51 5039' - 5044'	Pu-5/34	18	0	43	0	0	10	39	0	0	0	0	0	22	0	0	42	3	0	0
Core No. 51 5069' - 5074'	Pu-5/35	110	0	34	0	2	4	0	0	0	0	0	0	0	0	0	122	0	0	0
Core No. 52 5100' - 5105'	Pu-5/36	7	0	97	2	5	53	0	0	0	0	0	0	0	0	0	36	0	0	0
5130' - 5135'	Pu-5/37	126	0	16	8	0	21	3	4	0	0	0	0	2	0	7	63	0	0	0
5160' - 5165'	Pu-5/38	164	0	27	0	0	4	2	7	0	0	0	0	30	0	1	6	3	0	0
Core No. 53 5190' - 5207'	Pu-5/39	6	0	50	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Core No. 53 5223' - 5240'	Pu-5/40	9	0	46	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
5250' - 5255'	Pu-5/41	38	0	77	0	0	0	0	1	0	0	0	0	0	0	7	1	0	0	0
5280' - 5285'	Pu-5/42	60	0	26	0	0	0	2	0	0	0	0	0	0	0	8	0	0	0	0
5310' - 5315'	Pu-5/43	0	0	9	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0
5340' - 5345'	Pu-5/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
5370' - 5375'	Pu-5/45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Core No. 54 5415' - 5420'	Pu-5/46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0

Depth (Ft.)	Sample Nos.	H. wilcoxonii	D. tanii	R. minuta	Rhabdolithus spp.	P. hermosus	S. predistentus	S. anarrhopus	S. moriformis	M. flos	R. umbilica	R. dictyoda	D. tanii nodifer	E. formosa	C. latipons	S. rhombiformis	M. inversus	N. fulgens	R. callida	D. barbadiensis	D. saipanensis	D. kuepperi
4075' - 4080'	Pu-5/1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 21 4085' - 4095'	Pu-5/2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 22 4107' - 4112'	Pu-5/3	0	1	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 24 4137' - 4139'	Pu-5/4	0	1	5	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 27 4169' - 4174'	Pu-5/5	0	0	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 27 4179' - 4183'	Pu-5/6	0	1	0	3	0	3	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 31 4239' - 4244.5'	Pu-5/7	0	0	2	10	0	0	0	6	1	1	1	0	0	0	0	0	0	0	0	0	0
Core No. 32 4255' - 4260'	Pu-5/8	0	0	4	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 32 4285' - 4288'	Pu-5/9	0	0	0	0	1	5	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0
Core No. 34 4323' - 4328'	Pu-5/10	0	1	1	2	1	10	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Core No. 35 4334' - 4339'	Pu-5/11	0	0	0	3	0	6	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0
Core No. 36 4379' - 4384'	Pu-5/12	0	0	4	1	0	4	0	0	2	1	0	5	1	0	0	0	0	0	0	0	0
Core No. 36 4409' - 4414'	Pu-5/13	0	0	5	0	0	6	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0
Core No. 37 4441' - 4446'	Pu-5/14	0	0	0	0	0	5	0	0	0	1	11	1	2	0	0	0	0	0	0	0	0
Core No. 38 4471' - 4476'	Pu-5/15	0	0	0	0	0	2	0	0	0	2	6	0	2	2	1	0	0	0	0	0	0
Core No. 39 4502' - 4507'	Pu-5/16	0	0	0	0	0	7	0	0	0	0	10	4	1	0	0	1	0	0	0	0	0
Core No. 39 4532' - 4537'	Pu-5/17	0	0	0	0	0	10	0	0	0	0	6	0	2	0	0	2	0	0	0	0	0
Core No. 40 4562' - 4567'	Pu-5/18	0	0	0	0	0	14	0	0	2	0	8	0	2	0	0	2	0	0	0	0	0
Core No. 41 4592' - 4597'	Pu-5/19	0	0	0	5	0	18	0	0	0	67	8	0	3	0	0	6	0	0	0	0	0
Core No. 41 4622' - 4627'	Pu-5/20	0	0	0	16	0	18	0	0	0	32	11	0	6	0	0	0	0	0	0	0	0
Core No. 42 4652' - 4657'	Pu-5/21	0	0	0	19	0	30	0	0	0	54	6	0	5	0	0	0	2	2	0	0	0
Core No. 43 4678' - 4683'	Pu-5/22	0	0	0	6	0	7	0	0	0	70	6	0	3	0	0	0	0	0	0	0	0
Core No. 43 4708' - 4713'	Pu-5/23	0	0	0	18	0	9	0	0	0	77	6	0	3	0	0	0	0	0	0	0	0
Core No. 44 4738' - 4743'	Pu-5/24	0	0	0	14	0	6	0	0	0	80	17	0	3	0	0	0	0	0	0	0	0
4770' 4775'	Pu-5/25	0	2	0	12	0	2	0	0	0	55	12	3	2	0	0	2	0	4	0	0	0
Core No. 46 4800' - 4805'	Pu-5/26	0	0	0	4	0	4	0	0	0	34	23	0	5	0	0	0	0	27	2	3	0
Core No. 46 4835' 4840'	Pu-5/27	0	0	0	9	0	3	0	0	0	50	16	0	3	0	0	3	0	18	3	0	0
Core No. 47 4860' - 4865'	Pu-5/28	0	0	0	7	0	4	0	0	0	12	5	0	3	0	0	0	0	10	0	0	0
Core No. 47 4890' - 4895'	Pu-5/29	0	0	0	3	0	3	0	0	0	11	9	2	4	0	0	0	0	13	0	0	0
Core No. 48 4920' - 4925'	Pu-5/30	0	0	0	6	0	3	0	0	0	4	8	0	2	0	0	4	0	25	0	0	1
Core No. 49 4950' - 4955'	Pu-5/31	0	0	0	5	0	3	0	0	0	4	14	0	0	0	0	0	0	12	0	3	0
Core No. 49 4980' - 4985'	Pu-5/32	0	0	0	8	0	21	0	0	0	2	46	0	3	0	0	4	0	3	0	2	0
Core No. 50 5010' - 5015'	Pu-5/33	0	0	0	5	0	20	0	0	0	31	61	3	11	0	0	3	0	8	3	7	0
Core No. 51 5039' - 5044'	Pu-5/34	0	0	0	0	0	0	0	0	0	53	31	2	15	0	0	3	0	5	4	3	0
Core No. 51 5069' - 5074'	Pu-5/35	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	1	0	19
Core No. 52 5100' - 5105'	Pu-5/36	0	2	0	0	0	0	0	0	11	0	4	0	2	2	0	10	0	0	3	2	43
5130' - 5135'	Pu-5/37	0	0	0	4	0	0	30	0	0	0	0	0	3	0	0	0	0	0	3	0	2
5160' - 5165'	Pu-5/38	0	0	0	3	0	0	18	0	0	1	0	0	0	0	3	0	0	1	0	0	1
Core No. 53 5190' - 5207'	Pu-5/39	0	0	0	0	0	0	16	0	0	0	0	0	0	0	3	0	0	0	0	0	0
Core No. 53 5223' - 5240'	Pu-5/40	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	2	0	0	0	0	0
5250' - 5255'	Pu-5/41	0	0	0	0	0	0	39	1	0	0	0	0	0	0	0	2	0	0	0	0	0
5280' - 5285'	Pu-5/42	0	0	0	0	0	3	60	0	0	0	0	0	0	0	0	1	0	0	0	0	0
5310' - 5315'	Pu-5/43	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5340' - 5345'	Pu-5/44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5370' - 5375'	Pu-5/45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 54 5415' - 5420'	Pu-5/46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Depth (Ft.)	Sample Nos.	C. eodela	S. spiniger	C. grandis	C. bidens	S. furcatolithoides	C. consuetus	T. orthostylus B	D. mohleri	D. mahmoudii	D. lodoensis	M. decoratus	T. eminens	F. tympaniformis	H. kleinpelli	Q. gothicum	Q. garneri	E. robusta	P. bisulcus	P. dimorphosus	P. martinii	N. distentus
4075' - 4080'	Pu-5/1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 21 4085' - 4095'	Pu-5/2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 22 4107' - 4112'	Pu-5/3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 24 4137' - 4139'	Pu-5/4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 27 4169' - 4174'	Pu-5/5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 27 4179' - 4183'	Pu-5/6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 31 4239' - 4244.5'	Pu-5/7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 32 4255' - 4260'	Pu-5/8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 32 4285' - 4288'	Pu-5/9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 34 4323' - 4328'	Pu-5/10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 35 4334' - 4339'	Pu-5/11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 36 4379' - 4384'	Pu-5/12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 36 4409' - 4414'	Pu-5/13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 37 4441' - 4446'	Pu-5/14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 38 4471' - 4476'	Pu-5/15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 39 4502' - 4507'	Pu-5/16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 39 4532' - 4537'	Pu-5/17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 40 4562' - 4567'	Pu-5/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 41 4592' - 4597'	Pu-5/19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 41 4622' - 4627'	Pu-5/20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 42 4652' - 4657'	Pu-5/21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 43 4678' - 4683'	Pu-5/22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 43 4708' - 4713'	Pu-5/23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 44 4738' - 4743'	Pu-5/24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4770' 4775'	Pu-5/25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 46 4800' - 4805'	Pu-5/26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 46 4835' 4840'	Pu-5/27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 47 4860' - 4865'	Pu-5/28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 47 4890' - 4895'	Pu-5/29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 48 4920' - 4925'	Pu-5/30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 49 4950' - 4955'	Pu-5/31	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 49 4980' - 4985'	Pu-5/32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 50 5010' - 5015'	Pu-5/33	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 51 5039' - 5044'	Pu-5/34	0	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 51 5069' - 5074'	Pu-5/35	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 52 5100' - 5105'	Pu-5/36	3	0	0	1	0	3	3	1	8	8	0	0	0	0	0	0	0	0	0	0	0
5130' - 5135'	Pu-5/37	0	1	0	0	0	0	0	0	0	0	2	2	8	1	0	0	0	0	0	0	0
5160' - 5165'	Pu-5/38	0	0	0	0	5	0	0	0	0	0	0	5	6	0	1	1	2	5	3	3	2
Core No. 53 5190' - 5207'	Pu-5/39	0	0	0	3	0	0	0	0	0	0	0	24	16	0	0	0	19	86	3	35	3
Core No. 53 5223' - 5240'	Pu-5/40	0	0	0	0	0	0	0	0	0	0	1	30	18	7	0	2	13	67	1	42	0
5250' - 5255'	Pu-5/41	0	0	0	0	0	0	0	0	0	0	0	24	37	7	1	1	7	22	0	7	0
5280' - 5285'	Pu-5/42	0	0	0	0	0	0	0	0	0	0	0	8	36	0	2	3	3	16	0	13	0
5310' - 5315'	Pu-5/43	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	1	4	0	4	0
5340' - 5345'	Pu-5/44	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
5370' - 5375'	Pu-5/45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Core No. 54 5415' - 5420'	Pu-5/46	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	1	0	0	0	0	0

Depth (Ft.)	Sample Nos.	C. tenuis	W. barnesae	W. manivitae	M. staurophora	S. crenulata	C. ehrenbergii	E. gorkae	M. apertus	A. parca parca	E. macellus	E. distichus	T. tovae	P. cretacea	C. daniae	Q. trifidum	E. eximius	P. sigmoides	N. modestus	C. ovalis	F. pileatus	F. schaubii	P. fibuliformis	M. murus	P. grandis	M. undosus	Lithraphidites spp.	A. cymbiformis	G. obliquum	C. amphipons	C. litterarius	C. kamptneri	P. stoveri	E. turriseiffelii
4075' - 4080'	Pu-5/1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 21 4085' - 4095'	Pu-5/2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 22 4107' - 4112'	Pu-5/3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 24 4137' - 4139'	Pu-5/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 27 4169' - 4174'	Pu-5/5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 27 4179' - 4183'	Pu-5/6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 31 4239' - 4244.5'	Pu-5/7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 32 4255' - 4260'	Pu-5/8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 32 4285' - 4288'	Pu-5/9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 34 4323' - 4328'	Pu-5/10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 35 4334' - 4339'	Pu-5/11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 36 4379' - 4384'	Pu-5/12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 36 4409' - 4414'	Pu-5/13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 37 4441' - 4446'	Pu-5/14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 38 4471' - 4476'	Pu-5/15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 39 4502' - 4507'	Pu-5/16	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 39 4532' - 4537'	Pu-5/17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 40 4562' - 4567'	Pu-5/18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 41 4592' - 4597'	Pu-5/19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 41 4622' - 4627'	Pu-5/20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 42 4652' - 4657'	Pu-5/21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 43 4678' - 4683'	Pu-5/22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 43 4708' - 4713'	Pu-5/23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 44 4738' - 4743'	Pu-5/24	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4770' 4775'	Pu-5/25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 46 4800' - 4805'	Pu-5/26	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 46 4835' 4840'	Pu-5/27	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 47 4860' - 4865'	Pu-5/28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 47 4890' - 4895'	Pu-5/29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 48 4920' - 4925'	Pu-5/30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 49 4950' - 4955'	Pu-5/31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 49 4980' - 4985'	Pu-5/32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 50 5010' - 5015'	Pu-5/33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 51 5039' - 5044'	Pu-5/34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 51 5069' - 5074'	Pu-5/35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 52 5100' - 5105'	Pu-5/36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5130' - 5135'	Pu-5/37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5160' - 5165'	Pu-5/38	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 53 5190' - 5207'	Pu-5/39	2	4	2	1	2	2	2	3	2	3	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Core No. 53 5223' - 5240'	Pu-5/40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5250' - 5255'	Pu-5/41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5280' - 5285'	Pu-5/42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5310' - 5315'	Pu-5/43	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5340' - 5345'	Pu-5/44	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5370' - 5375'	Pu-5/45	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Core No. 54 5415' - 5420'	Pu-5/46	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Depth (Ft.)	Sample Nos.	Total	Preservation State	No. Nannofossils per Field of View
4075' - 4080'	Pu-5/1	302	2	4.079
Core No. 21 4085' - 4095'	Pu-5/2	309	2	3.367
Core No. 22 4107' - 4112'	Pu-5/3	308	2	8.556
Core No. 24 4137' - 4139'	Pu-5/4	328	2	15.619
Core No. 27 4169' - 4174'	Pu-5/5	306	2	6.8
Core No. 27 4179' - 4183'	Pu-5/6	303	2	19.813
Core No. 31 4239' - 4244.5'	Pu-5/7	320	1.5	22.071
Core No. 32 4255' - 4260'	Pu-5/8	310	1.5	22.143
Core No. 32 4285' - 4288'	Pu-5/9	308	1.5	25.75
Core No. 34 4323' - 4328'	Pu-5/10	304	1.5	21.714
Core No. 35 4334' - 4339'	Pu-5/11	313	1.5	20.867
Core No. 36 4379' - 4384'	Pu-5/12	307	1.5	34
Core No. 36 4409' - 4414'	Pu-5/13	302	1.5	13.727
Core No. 37 4441' - 4446'	Pu-5/14	308	2	20.4
Core No. 38 4471' - 4476'	Pu-5/15	308	2	14.714
Core No. 39 4502' - 4507'	Pu-5/16	318	2.5	17.5
Core No. 39 4532' - 4537'	Pu-5/17	308	2.5	11.846
Core No. 40 4562' - 4567'	Pu-5/18	315	2.5	16.58
Core No. 41 4592' - 4597'	Pu-5/19	318	1.5	8
Core No. 41 4622' - 4627'	Pu-5/20	310	2.5	7.209
Core No. 42 4652' - 4657'	Pu-5/21	300	2	7.143
Core No. 43 4678' - 4683'	Pu-5/22	310	2	7.488
Core No. 43 4708' - 4713'	Pu-5/23	314	2	7.974
Core No. 44 4738' - 4743'	Pu-5/24	308	2	7.163
4770' 4775'	Pu-5/25	300	2	6.977
Core No. 46 4800' - 4805'	Pu-5/26	305	2.5	8.297
Core No. 46 4835' 4840'	Pu-5/27	317	2.5	5.139
Core No. 47 4860' - 4865'	Pu-5/28	300	2.5	7.795
Core No. 47 4890' - 4895'	Pu-5/29	321	2.5	8.308
Core No. 48 4920' - 4925'	Pu-5/30	314	2.5	8.722
Core No. 49 4950' - 4955'	Pu-5/31	319	2.5	7.595
Core No. 49 4980' - 4985'	Pu-5/32	309	2.5	7.023
Core No. 50 5010' - 5015'	Pu-5/33	320	2.5	7.442
Core No. 51 5039' - 5044'	Pu-5/34	300	2.5	7.227
Core No. 51 5069' - 5074'	Pu-5/35	306	2.5	1.01
Core No. 52 5100' - 5105'	Pu-5/36	305	2	3.188
5130' - 5135'	Pu-5/37	306	2	3.352
5160' - 5165'	Pu-5/38	306	2	3.483
Core No. 53 5190' - 5207'	Pu-5/39	300	2	0.856
Core No. 53 5223' - 5240'	Pu-5/40	300	2.5	15
5250' - 5255'	Pu-5/41	300	1.5	0.221
5280' - 5285'	Pu-5/42	301	2	0.231
5310' - 5315'	Pu-5/43	300	2	0.19
5340' - 5345'	Pu-5/44	302	2.5	0.2904
5370' - 5375'	Pu-5/45	300	2.5	0.277
Core No. 54 5415' - 5420'	Pu-5/46	300	2.5	0.19

RANGE CHART